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THE ELECTRIC LIGHT WORKS OF BOULEVARD RICHARD LENOIR, PARIS.

It dates only from the day when four prominent companies obtained from the municipal council of Paris a grant for the lighting of a section that this so agreeable and hygienic a mode of lighting has entered definitely into our habitudes. The movement was tardy, but, none the less for that, it has, from the beginning, been so extremely earnest, that its progress is a most interesting fact to record. It is characterized by the rapid progression of the central stations in importance.

In the first place, it was Milde, Clerc & Co. who, in the Faubourg Montmartre, installed dynamos of the Edison type, of feeble power, actuated, through belts, by horizontal slow-running engines. Then the Society for the Transmission of Power by Electricity equipped a small establishment in Bondy Street with Weyher & Richmond semi-stationary engines, which, through belts, actuated Breguet dynamos with Gramme armatures, for supplying the surrounding theaters—the Renaissance, the Porte Saint Martin, the Ambigu and the Folies-Dramatiques. But this installation, as soon as public lighting was authorized, became inadequate, and the society, at the suggestion of Mr. Leon Levy, its then manager, did not hesitate to transform the works completely, and to establish the first central station worthy of our capital. This is provided with four Weyher & Richmond vertical compound engines of 150 h. p. and 160 revolutions, which, through belts, actuate four Desrozier dynamos of the same power, running at a velocity of 300 revolutions. Scarcely was the transformation completed when the necessity was seen of making new improvements in order to save space, which is so dear at Paris. The Derozier dynamo lends itself admirably to low speeds, and, consequently, to a direct coupling with the motor; so the society, during the next year, installed in succession three centers of distribution—one on Filles-Dieu Street, one at the railway station of the North, and one on Boulevard De la Villete, with the same steam motors, actuating directly, through an elastic coupling of the Raffard system, eleven Desrozier dynamos of the same power, revolving only 160 times per minute.

The Edison Company, which had become purchaser of the center of the Faubourg Montmartre, and which had transformed it as far as space permitted, established, at this epoch, a new works on Trudaine Avenue, at the same time that the Parisian Compressed Air Company, founded for the exploitation of the processes of V. Popp, was installing its central works of the Boulevard Richard-Lenoir. The principles of these two works are the same. The direct coupling triumphs, and the units increase in power. In both, there are steam engines, of 300 h. p., with a velocity of 135 revolutions, actuating, through an elastic coupling, at the right and the left, two electric machines, of half less power.

It may be said that these two works represent the most perfect installations that have been created up to the present time. For this reason they are deserving of being studied in detail, and particularly the works on the Boulevard Richard-Lenoir, which proceed from a theoretic idea entirely different from those in use either by the Edison Company or by the Society for Lighting by Electricity.

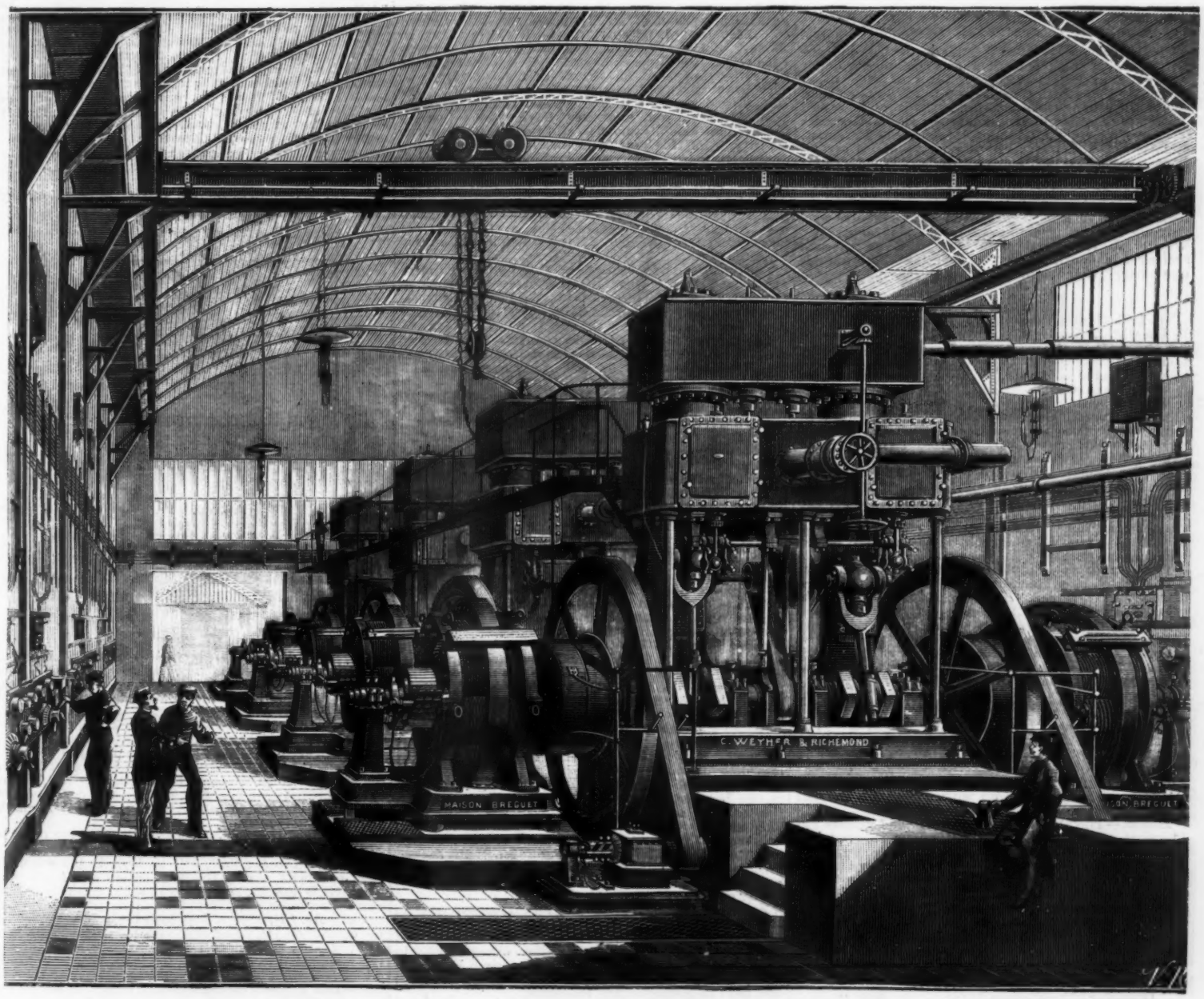
GENERAL DESCRIPTION OF THE POPP SECTION.

While the two other societies connect their subscribers' lines directly with the generating works, and are consequently obliged to operate day and night, and to follow with their motors all the variations in consumption, the Popp Company does not deliver the current directly to the consumers, but charges batteries of accumulators installed in sub-stations, whence are derived the circuits that supply the subscribers.

These circuits have no connection with the charging lines, and this leaves a wide latitude to the company in the choice of the electro-motive force of the generating works without any prejudice to the security of the service. In fact, the Boulevard Richard-Lenoir works, at certain hours, furnish a current of a potential of 2,400 volts.

As the charging of the exhausted batteries always requires the same intensity of current and an electromotive force that may be rendered constant by a proper choice of the number of sub-stations mounted in tension, the units of the generating works always operate under full charge, that is to say, in the best conditions of rendering.

Finally, the utilization of a high voltage permits of supplying sub-stations very distant from the generating ones, and, consequently, diminishes the number of the central stations indispensable. It is true that the accumulators represent a fixed capital equivalent to



GENERAL VIEW—CENTRAL ELECTRICAL STATION, PARIS.

the electric *materiel* that they replace, and that the keeping of them in repair is five per cent. higher, but the collecting of the generating groups into a single center and their constant work under full power presents such advantages that we ought to expect from this experiment a confirmation of the economic value of the system.

It has appeared to us of interest to give here a general idea, and then to describe the generating works with some detail.

These works, situated on the Boulevard Richard-Lenoir, are now the most important source of electric energy distributed in the section conceded to the Parisian Compressed Air Company; but, as a principle, this district has to be supplied by four works of nearly equal power, situated as follows: Cité du Retiro, near the Madeleine, Commercial Exchange, Dieu Street, and Boulevard Richard-Lenoir. Each of them is interposed in a closed circuit. The four circuits traverse, in tension, batteries of accumulators placed in twenty-five sub-stations. To guard against the chance of an accidental stoppage of a generating station, three of the sub-stations are situated upon two circuits, and, through the maneuvering of special commutators, permit of uniting the two circuits so as to form but one.

The generating stations furnish the sub-stations with a current of constant intensity equal to 250 amperes. The electro-motive force in a circuit may vary from 400 to 2,400 volts, on grouping in tension from 1 to 6 dynamos whose electro-motive force is 400 volts. The batteries of accumulators in each sub-station include 65 elements of 300 kilogrammes of plates. Each sub-station has at least two batteries, one of which is being charged upon the circuit of the dynamos while the other is discharging itself upon the secondary line of the subscribers.

THE BOULEVARD RICHARD-LENOIR WORKS.

These works, as we have just said, furnish the section normally with a current of 250 amperes, under 2,400 volts, by means of three groups of 300 h. p. A fourth, and identical, group serves to take the place of one of the others when necessary.

The works, consequently, comprise: Eight Desrozier intensive, multipolar dynamos, constructed by Breguet, and each of which gives, at a velocity of 135 revolutions, a current of 250 amperes, under 400 volts; four Weyher & Richmond triple expansion motors, each capable of an effective 300 h. p.; four Babcock & Wilcox multitubular generators, constructed at Creusot, registered at 12 kilogrammes, and each capable of vaporizing 3,100 kilogrammes of water per hour; two Weyher & Richmond automatic condensers, each serving as a substitute for the other; two feed pumps, one purifier, and one brick chimney.

THE BOILER HOUSE.

The boiler house is a structure 17·5 meters in length by 14·5 in width. The level of the earth has been lowered here below that of the public way. This arrangement is eminently favorable to the maneuvers, and gives the steam collector a constantly ascending slope to the motors. Each of the Babcock & Wilcox generators presents a heating surface of 226 square meters, and is capable of producing, normally, 14 kilogrammes of steam per square meter of heating surface. Experiments extending over a long period have fixed the vaporization at 9·5 kilogrammes per kilogramme of coal. Two generators suffice for the normal running, but a third is fired up in the busiest hours.

Economizer.—On coming from the generators, the flames and products of combustion pass into a Lemoine "economizer," an apparatus formed of vertical tubes, in which the feed water is obliged to circulate before reaching the pumps.

These tubes are completely enveloped by the lost flames, which raise the water to a mean temperature of about forty degrees. Mechanical cleaners, constantly actuated by a small 3 h. p. steam motor (Tangye system), cast the deposits that form upon the tubes into a flue.

Feed Pumps.—Two donkey pumps serve as a substitute one for the other, and assure the continuous feed of the generators under pressure.

THE ENGINE ROOM.

The engine room is 21 meters in length by 12 in width. It is in this limited space that, thanks to the particular adoption of vertical high-speed motors and of low-speed directly-coupled dynamos, that one has succeeded in placing generators of electricity that permit of furnishing the section with a constant current of 800,000 watts.

Motors.—The four Weyher & Richmond motors are identical, and are of the vertical type, with triple expansion. At a velocity of 135 revolutions, and under a steam pressure of 12 kilogrammes, each of these motors gives a disposable power of 300 horses.

These motors are very carefully constructed. The consumption of steam per horse is less than 8 kilogrammes. The constancy of the velocity is assured by a Watts governor, which regulates the opening of the admission valve. The dimensions of these motors are as follows:

Diameter of small cylinder.....	390 mm.
Diameter of medium cylinder.....	580 "
Diameter of large cylinder.....	720 "
Common stroke of pistons.....	450 "

Each motor is provided with two powerful fly wheels, which serve also for the impulsion of the dynamos. The lubrification of the parts in motion is done with grease, through a special arrangement that renders it automatic.

Raffard Coupling.—The motors are connected at the right and left with two Desrozier dynamos, through the intermedium of elastic couplings of the Raffard system. The object of this ingenious joint, which is in everyday use in the electric installations on board of ships, is to unite the shafts of the motor and dynamo, without transmission, end to end. To this effect, pins in proper number are riveted upon the fly wheel according to a circumference concentric with the shaft. The dynamo is provided with a disk which carries an equal number of pins distributed over a smaller circumference than the preceding. Rubber rings afterward connect each of the pins of the fly wheel of the motor with one of the pins of the disk of the dynamo. The impulsion thus obtained is given without shocks, and consequently without noise. Slipping is impossible, and the elasticity of the system permits of a perceptible change of level of one of the coupled shafts with respect to the other, without prejudice to the perfect working of the whole. Finally, as the mass of the dynamo is not in mechanical contact with the motor, it can be entirely insulated from the ground.

Generating Dynamos.—The mean diameter of the ring of armature wires of the eight dynamos is 1·41 meters. The normal velocity at the Richard-Lenoir works is 135 revolutions per minute. At this speed the dynamos give a current of 400 volts and 250 amperes, and require, each of them, a motive power of about 150 horses.

As the Desrozier dynamos are in so extensive use, and are so well known, it seems useless to enter into a description of them here. Those of the Boulevard Richard-Lenoir works are of the same type as the ones adopted by the Society for the Transmission of Power by Electricity in its four central stations.

As well known, the characteristic properties of this kind of machine are: Absence of iron in the armature; the extremely efficacious ventilation due to the very good arrangement of the wires, and the remarkable lightness of the mass in motion. These properties secure for the machine, and particularly for the insulator of the induced wires, an exceptional solidity.

The question of insulation is one of prime importance in the Boulevard Richard-Lenoir works. The generating works have, in fact, to furnish the general line of the section with a current of 250 amperes under an electro-motive force capable of reaching 2,400 volts. This current, produced by units of 250 amperes under 400 volts, requires, therefore, at certain hours, the putting in tension of six dynamos. At this moment the difference of potential between the armature of the last of the generating dynamos and the earth is 2,400 volts. It will be conceived that the least damage to the insulation of the armature must give rise to very grave accidents, to which, consequently, the Desrozier dynamos are less exposed than any other. Special precautions, moreover, have been taken by the Breguet establishment to still further increase the security from this point of view. The collectors are doubly insulated, and are completely disengaged, so as to permit of their being easily cleaned while in operation. They are provided with but four brushes, which are arranged in two diametrically opposite planes, despite the multiplicity of the poles of the dynamos. Finally, the machines rest, though thick pieces of glass, upon large wooden frames which insulate them from the earth.

The operation of these dynamos has been irreproachable from the beginning. The performance of the collectors is perfect. No spark is observed at the brushes, and yet the duration of the daily operation is twenty hours in full charge.

The most remarkable fact to point out is the progressive augmentation of the insulation of the armatures from the time of their being put in service. This insulation, which was but about three megohms at the beginning, is now, according to the machines, from 200 to 250 megohms, and is ever tending to increase. The rendering has been found to be equal to 93 per cent. (excitation deducted), a figure which is eminently satisfactory, especially seeing the low speed of the machines.

The inductors of these machines are excited by small separate dynamos set in motion through the intermedium of belts mounted upon the fly wheels of the steam motors.

Maneuvering Boards.—The brushes of the eight dynamos are connected by thoroughly insulated conductors with eight identical boards, each carrying one commutator, one amperemeter and one voltameter. These boards, constructed by the Breguet establishment, are interposed in the line and permit (1) of putting the line in short circuit when the corresponding dynamo is not running; (2) of introducing the corresponding dynamo into the line without having to open the latter, and, consequently, without interrupting the charge of the secondary stations; and (3) of regulating the electro-motive force of each of the dynamos through the maneuvering of a rheostat placed in the field.

Before starting from the generating works, the line passes over an indicating board designed to notify the managing electrician of the variations in intensity that may occur during the running.

The essential apparatus of this board is an amperemetric balance. The current of the line circulates in this balance and keeps the beam of it horizontal as long as the variations are insignificant. A lowering or a sensible increase of the intensity sets in motion a bell that rings as long as the regulation is not accomplished. An amperemeter interposed in the line and placed alongside of the balance indicates the direction of the variation.

Automatic Current Breaker and Interrupter.—As the current produced at the works is designed solely for charging accumulators, a current breaker has had to be installed for breaking the line automatically in case the amperemetric balance has not given the necessary indications, or the electrician in charge has not had time to maneuver the rheostats.

The principle of such apparatus is well known. The one adopted by the Parisian Compressed Air Company differs from other apparatus of the same kind only in that it includes, besides, an automatic interrupter, which, with the mercury contact, assures the breakage of the two poles of the line at the time of setting the apparatus in operation.

CONDENSATION ROOM.

The works include, in addition: (1) a condensation room, with two Weyher & Richmond condensers, each sufficient to condense the steam of three motors of the works, and (2) a Desrumeaux purifier designed to precipitate from the waters of condensation of the Saint Martin Canal the impurities prejudicial to the keeping of the generators in good order.

SERVICE OF THE WORKS.

The works are set in operation daily at midnight and are not stopped until 10 o'clock at night of the next day.

Ordinarily, the charging of one battery in each sub-station is effected while the other is being discharged upon the lines of the subscribers; but from 6 o'clock in the evening until midnight, the sub-stations are sometimes so overburdened that the two batteries that they are provided with may have to operate simultaneously.

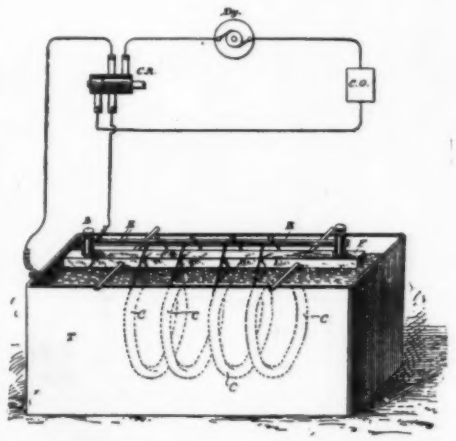
A description of the sub-stations and of their service, however, we shall not enter too far into in the present article. We shall revert to the subject later on, after precise figures relative to an operation of an appreciable duration may be added to the description and increase the interest of it.—*Le Genie Civil.*

IMPROVED METHOD OF TESTING INSULATED WIRES.

IN covering electric conductors it frequently happens that particles of dust or other foreign matter lodge upon the insulating material or otherwise become incorporated within it, or that the material itself contains fine cracks or irregularities in thickness which lower its insulating power. A very large percentage of wires, after being coated, contain such faults, and it is a great desideratum to be able to locate them expeditiously and efficiently. Various modes of testing have been resorted to, but many of them require too much time for use where a large number of coils of wire are to be tested. Recently, however, Mr. Richard Varley, Jr., of Englewood, N. J., has devised a method, called by him the "flash test," which is based upon the fact, discovered by him, that if an insulated wire be connected to one terminal of an electric circuit the other terminal of which is placed in close relation to the insulating covering throughout its length, and the circuit charged with a current of high potential, a flash will be exhibited at such points of the conductor as are within range of disruptive discharge.

Mr. Varley's arrangement consists in charging a circuit one terminal of which is connected with the wire to be tested, and the other placed in close relation to the insulating covering with a current of sufficient electromotive force to produce a flash at points where faulty insulation exists. The terminals of the circuit are brought into the proper relation to create the flash by surrounding the insulated covering with water before charging the circuit.

As will be seen in the accompanying illustration, D *y*



"FLASH" TEST FOR INSULATED WIRES.

represents a dynamo, in the circuit of which is interposed a series of coils of insulated wire, C C C, which are to be tested. A current reverser, C R, is introduced to produce periodical reversals of current. One terminal of the circuit is connected to a binding post, B, and the other electrically connected with the water in the tank, T. The terminals of the coils are inserted between two metallic bars, E E, supported in posts on the wooden beam, F, supported on the tank, the bars being electrically connected with the post, B. Thus the circuit between the wire forming the coils and the water is incomplete unless leakage should exist through the insulating covering.

If now the circuit be charged with a current of from fifteen hundred to two thousand volts, and the current reverser operated, a flash will be seen in the water at such points of any of the coils where the insulating covering is insufficient to resist such a charge. The current reverser is operated at about sixty reversals per minute. If, after a flash is developed, the current be continued, the insulation would rapidly be destroyed, and, in order to prevent such a result, a cut-out is included in the circuit, having a lagging contact which renders it inactive except when a deficiency in insulation in the wire being tested exists. A weight on the armature is adjusted so that it normally holds the testing circuit closed. When the armature is tilted, the weight is thrown past the center and holds the circuit open, thus acting as a cut-out.

The coils which show a flash are removed from the tank, and the operation is repeated with the others.—*Electrical Engineer.*

IT appears, from the complete edition of the works of Huyghens, now in course of publication at the Hague, that as soon as he had succeeded in applying the pendulum to the regulating of clocks, claims were set up for priority in the invention. The best founded claims were those of Galileo, which were championed by Prince Leopold de Medici. According to the formal statement drawn up by Viviani, Galileo had conceived the idea, but failed to make the application of it. He had a pendulum connected with wheel work, but omitted to provide any weights, springs, or other means of keeping the machinery in motion.

THE LITTLE GEORGIA MAGNET.

WE give a number of sketches of the latest wonder who is taking the town of London by storm. On Saturday afternoon a private seance took place at the Alhambra, when the Magnet did some wonderful things. The lecturer, who introduced Miss Abbott, stated that she was born in Georgia, and was the youngest child of a family of thirteen, and the only one possessed of the singular force she exerts, and that

SHE LIFTS A MAN BY THE HEAD.

this force, whatever it may be, was discovered in her when she was seven years of age. He also informed the company that she is capable of exercising this force at any moment and at any place. Annie Abbott is not a muscular woman by any means, and the lecturer asserted that without this force she could not lift 100 lb. to save her life. Edison, he said, is of opinion that the force which she exercises is some kind of electricity which is incapable of scientific explanation. A committee of about twenty gentlemen was selected from the audience, several of them being well known professional gentlemen of the highest integrity. Mr.

SHE LIFTS SIX MEN ON ONE CHAIR.

C. B. Harness, the electrician; Mr. John Hollingshead, Mr. Horace Armitage, and Mr. J. G. Rhodes were among the number. The Little Magnet was dressed in a white satin evening costume, trimmed with sprays of flowers, with lappets over her bare arms. The first exhibition of her power was with a chair. One of the committee held in front of him a chair raised from the stage. The lady simply placed her hand flat on the wood, and the holder at once made desperate efforts to remain still, but was forced about wherever the operator led or pushed him. The chair was afterward held in a firm grip by five or six men. The moment she touched it with her open palm they all went stumbling about with their burden, and were utterly powerless to stand still. The men exerted themselves to the utmost to resist the impelling force, which is as invisible as it is irresistible, but the lady herself put forth no apparent exertion, or strain, and after each encounter she gave a pleasant smile, as if she quite enjoyed the fun. She next held the chair herself, and no amount of physical force could wrench it from her, or move her from her position. Her next test was to stand erect on one heel, holding a billiard cue in her open hands. Various members of the committee tried hard by taking hold of the cue to push her from her balance, but both the lady and the cue were as immovable as a mountain. It should be understood that

NO MAN CAN LIFT HER.

though the cue lay simply in her open palms, seven men tugging at it simultaneously failed to wrest it from her or to upset her equilibrium.

Miss Abbott next invited a member of the committee to be seated in a chair. The member, who must have weighed at least sixteen or seventeen stones, caused

FOUR MEN CANNOT TAKE THE BILLIARD CUE FROM HER OPEN HAND.

some laughter when he seated himself in the chair. The lady stood behind the chair, touched the outer rails with her open hands, and at once raised it with its bulky occupant. This feat gained for her hearty applause, which was renewed again when five men seated themselves one on top of the other in the chair, and the lady with the same magic touch lifted the whole of them, but they were no sooner up than, owing to want of equilibrium, they were upset all in a heap. A rocking chair was then introduced, and another Herculean member of the committee seated himself in it. He was enabled to rock himself to his

CANNOT ROCK WHILE HER HANDS TOUCH THE CHAIR

THE BOY CANNOT BE LIFTED WHILE HIS HANDS TOUCH HERS.

heart's content until the lady, walking to the chair, placed two fingers upon it, and fixed it as firmly as if it had been screwed to the stage. The moment her hand was removed from the chair the man was enabled to continue his rocking. A boy was the next medium selected for the exercise of her marvelous influence. He was made to stand facing the lady, who, holding the boy's hands in her own, imparted to him the power which she herself possesses, and while thus holding him two of the strongest men on the stage failed to move the boy, says a morning contemporary from whom we quote.—*Pall Mall Budget.*

AN EXPOSE OF THE ELECTRIC GIRL.

By NELSON W. PERRY, E.M.

"ELECTRICITY is a mysterious agent, therefore everything that is mysterious is electrical." This is the logic of the masses, and we find it worked for all (and more than) it is worth in electric belts, hair brushes, tooth brushes, hurricanes and electric or magnetic girls. "All cows have tails, but all animals that have tails are not cows," is the logic of the scientist. Now the so-called electric girl performs some feats that are totally incomprehensible to the average spectator, and which seem at first to set at defiance some of the most familiar mechanical laws. She certainly astonishes, but she is not electrical. I propose in this article, after stating some of the things that she does, to show how she does them, and that the agencies employed are the very ones that her feats seem to defy.

About the year 1883 vague rumors reached the North of the existence of a girl in Georgia possessed of extraordinary powers, supposed to be either magnetic or electrical, and a little later we heard of her appearing in public and finally in dime museums, where her performances astounded all beholders. This girl's name was Lulu Hurst, and she is described by Prof. Simon Newcomb (*Science*, Feb. 6, 1885, pp. 106, 107, 108), who thought the case of sufficient importance to warrant investigation, as follows: "Rosy country girl above medium height, but did not give the impression of muscular training; still, when she was introduced to those present (a committee of investigation of which Prof. Newcomb was one) the first thing which struck the writer was the weight of her arms. Shaking hands with her felt like moving the arm of a giant and led to the impression that she had a much better muscular development than would have been supposed." Her success was so phenomenal that she soon had many imitators, and the dime museum manager who could not exhibit an electric girl once in a while was not up with the times. I have seen many of these imitators, but not the genuine Lulu Hurst. I have had many conversations with people who have seen Miss Hurst, however, and I am led to believe that the imitators do the same things in the same way as she, and in some cases have improved upon her performances by greater expertness and by introducing new features.

The first performance I saw was in Cincinnati. Arriving at the museum a little early, I found a temporary platform or stage erected at one end of the hall. The supports for this platform were concealed by drapery. Not knowing the nature of the performance, it occurred to me to investigate what was beneath. Having satisfied myself that there was no trickery there, I awaited the performance. A little girl about fourteen years of age and slightly built was introduced as the "electric girl," and a general invitation was extended for any strong man among the spectators to step up to the stage. It so happened that a gentleman with whom I was acquainted responded. He was fully six feet high, broad shouldered and had considerable local reputation as an athlete, and he could not have weighed less than two hundred pounds. A stout stick about three feet long and as thick as a broom handle was handed to him, and he was told to grasp it in the middle with both hands, and with arms extended to hold it as rigid as possible. The little girl then placed the *palms* of her *open hands* on either end of the stick, as shown in Fig. 1, and after a few preliminary move-

FIG. 1.—THE ELECTRIC GIRL.

ments soon had this strong man staggering about the stage apparently completely at her mercy, and at one instant a timely cessation of her endeavors only prevented him from being hurled ignominiously off the stage to the floor three or four feet below. It was a sight not soon to be forgotten—the utter helplessness of this giant in the hands of such a child. When he came down from the platform I asked, "Well, how was it?" He replied, "I really do not know. She possesses a power against which I was helpless. I'd hate awfully to have her for a wife, but I'd give a good deal to know what's under that platform."

Three men then took hold of the stick, but she handled them as easily as she had my friend. Next an ordinary straight backed wooden chair was brought out, and on the request that a heavy man should come up, it was occupied by a man who satisfied the requirements. He gave his weight as 240 pounds and looked it. He was instructed to hold the chair down at all

hazards. The girl approaching from behind placed the palms of her *open hands* upon the two hind legs of the chair, and beginning with slight movements, she soon had the chair moving so rapidly around the platform that the man who was sitting in it could scarcely keep his seat. Then to exhibit her powers more fully, three men were invited to hold the chair down. They arranged themselves as shown in Fig. 2, but the result

FIG. 2.—THE ELECTRIC GIRL.

was the same as when the chair was occupied by but a single individual. My position was such that I could watch the movements of the girl very closely, and, while evidences of muscular exertion were not wanting, they were by no means commensurate with what seemed necessary to produce the results obtained. In fact the evidence of one's senses was that had she ten times the strength she really possessed, and had she exerted it all to the utmost, she must have failed.

One constituted as I am cannot see such things without desiring a solution of the mystery, and I set about trying experiments. I soon found a solution, and with a little practice never failed to repeat what I had seen in a satisfactory manner, *provided all the conditions were right.* These conditions are that the subjects shall be strong and strive to their utmost to oppose my efforts. If either of these requisites be wanting the experiment must be a failure.

In another city, where I happened to be recently, a magnetic girl was advertised, and as one of her performances was new to me, I went to see her, and accepted an invitation to a chair on the stage. Three other gentlemen also came up. While the lecturer was enlarging upon the girl's wonderful powers I had ample time to converse with my companions. I instructed them just how to hold themselves in each of the experiments, and promised that if they carried out my directions the girl could do nothing with them, and the seance would be a failure. The tricks already described were performed, and in each of them one or more of my companions were called upon to assist. I did not take part in these. In each of the performances they at first carried out to the letter my instructions, and the girl failed; but she complained so loudly that they would not do as she told them, and was so ably seconded in these complaints by her infuriated manager, that they were finally constrained to obey, and the performance proceeded successfully. The new (to me) trick was reserved to the last, and I was invited to take part. This is represented in Fig. 3. Another

FIG. 3.—THE ELECTRIC GIRL.

gentleman and myself were handed a strong stick, about four feet long, which we were told to grasp with both hands and hold in a vertical position. The girl placed her *open* hand against the side of the lower end, as shown, and we were told to press down as hard as we could. I know I used my utmost strength, and, presumably, my companion did also, but in spite of all our efforts we could not cause the stick to slide past her open hand. Had she grasped the stick in both hands with firm hold she could not have held it against the efforts of either of us alone. I was not long in experimenting on this, and in learning how it was done. It is one of the most effective tricks in the repertoire of the electric girl, and at the same time can be very easily acquired. As it throws so much light on the other tricks, I will explain it first.

The two men are required to stand side by side, and the girl, facing them, places the palm of her hand on the side of the stick away from her, or on that side toward which the men are facing. She is also careful to place her hand as far from theirs as possible, thus gaining considerable leverage. She begins by moving her hand up and down the stick, first with very slight, but with gradually increasing pressure, as if to make better contact. This diverts the stick from the perpendicular, and she tells them to hold it straight. As they endeavor to do this they are working to a very great disadvantage, having little or no leverage, whereas she has a foot or two. The strain on her is very slight, first, because of the leverage in her favor, and, second, because it is merely tensional in the direction of her arm. When she thinks she has sufficient pressure on her hand the order is given to the men to press down as hard as they can. They think they are exerting a tremendous vertical pressure, but the fact is their efforts are almost entirely consumed in keeping the stick vertical against her pull at the lower end. They know they are expending some energy in this way, but are confident that most of it is expended in vertical thrust. There is, of course, some of this, but their efforts to counteract her pull cause sufficient friction between her hand and the stick to support that thrust or its equivalent weight. To determine just what this weight was, I called in the assistance of two powerful men. We all weighed ourselves on a spring balance. One weighed 167 pounds, the other 161½ pounds, and I weighed 166 pounds. Now, if I remained on the scales while the other two were pressing down on the stick, the excess over 166 pounds indicated by the spring balance would be the measure of the vertical effort exerted by them. The result was astonishing. With these two men exerting every muscle to force the stick to slide past my open hand they failed, and the balance indicated in one instance but 191 pounds, and in another 190, thus making their united efforts in a vertical direction 35 and 24 pounds respectively. Most of their effort was, unknown to them, in a horizontal direction. If my arm took the direction of the resultant of these two forces, which it most naturally would, the strain on me would be merely tensional in the direction of the length of my arm.

In the experiment illustrated in Fig. 1 the subject is enjoined to hold the stick perfectly rigid. The girl, on account of the immense leverage she has, with but very slight pressure on the ends of the stick can move not only the stick, but the arms and body of the subject. This she does slightly at first, increasing her efforts gradually. These are opposed with increasing force until she thinks he is exerting himself sufficiently, when she suddenly either relaxes her efforts entirely or exerts them in another direction. Totally unprepared for this change of base, the victim is thrown off his balance and is then at her mercy. The stronger the man and the more he opposes her, the better. It is still easier to do this with two or three men than with one, for there is no concert of action between them, and after they are once off their balance, the girl's efforts need scarcely be more than directive. If this be done with some skill, the men will throw themselves, and little is left for the girl to do but to follow them up.

In the chair trick, ninety-nine men out of one hundred when told to hold the chair down will place their hands on the seat or arms of the chair and throw their weight almost entirely on their feet. If they do not do this at first, they will the moment they are conscious of the girl's effort to raise the chair, thus unconsciously assisting her. To raise the chair the operator merely pushes against the back of the seat; she does not lift. She is assisted in doing this by her knees, which she brings to bear against her elbows or forearms, and also by the leverage she has between the man's feet and her hands. Once the chair is raised ever so little, the hardest part is accomplished. She at once relaxes her efforts and he falls back, or by a sideways movement she shoves the chair to one or the other side. In either case he is off his balance, and skillful manipulation on her part before this balance is regained causes him to throw himself in almost any direction she desires with little expenditure of energy on her part.

The difficulty is not increased when another man sits in the first one's lap, and when there are three, arranged as in Fig. 2, the task is much simplified. It is evident that the third man acts as a counterpoise to the one in the chair, and the whole system resembles a balanced beam with center of gravity high, and, therefore, in a state of equilibrium approaching instability.

To perform these tricks successfully requires some expertness, but this may be acquired by a little practice. The most effective and yet the simplest of them all is that represented in Fig. 3. On the second or third attempt, a friend of mine performed it as successfully as the girl from whom I learned it.

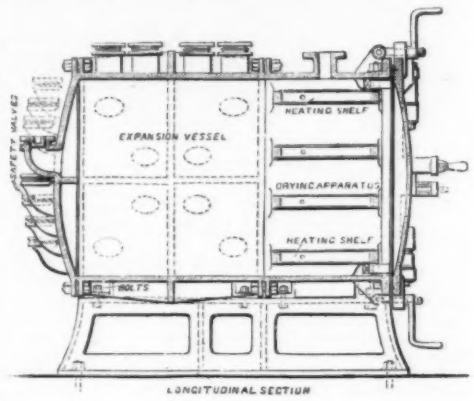
The above article was prompted by the following clipping from the editorial columns of the London *Electrical Review* of November 13:

The *Daily News* last week gave a very thrilling and exciting account of the remarkable feats performed by an American lady in the presence of a number of doctors and well known scientists, including Profs. Crookes, Perry, and Dr. Lodge. Our contemporary credits Mrs. Abbott with bringing from the United States the latest puzzle in electrical phenomena, for she modestly ascribes the seemingly incredible feats which she accomplishes to electricity or to animal magnetism. Her peculiarity lies in her marvelous strength, although there was no unusual muscular development in her arms or shoulders, neither was any strenuous exertion displayed by her. Mrs. Abbott lifted four gentlemen, packed somehow on a wooden chair, without any apparent undue exertion. Regarding these mysterious actions Dr. Lodge wrote to the *Daily News* on the 8th inst., in which letter he states that it was half suggested in their description that the surprising feats were supposed by those present to be attributable in some occult way to electricity or magnetism, and, as he was present at the time, he thought it incumbent on him to state that, whereas the feats themselves were, on the whole, very fairly described in the *Daily News* article, there was, in his opinion, not sufficient ground for believing them to be accomplished by anything more abnormal than than the extraordinary muscular power and skill of a small woman in good training. Profs. Crookes and Perry also disclaim that the feats witnessed were in any way attributable to animal electricity or magnetism which the lady may have possessed in a special degree, but we can well understand how it might be possible to bring electro-magnetism to the assistance of the performer in the lifting and non-lifting experiments.—*Electrical Review, London.*

When men of such world-wide reputations as those enjoyed by our own Simon Newcomb, and Profs. Crookes and Perry and Dr. Oliver Lodge, of England, deem these displays worthy of investigation, and when the editor of one of the leading electrical journals of Great Britain sees fit to suggest the agency of electromagnetism as a solution of the problem, it seemed to me it would not be uninteresting to readers of *Electricity* to hear the true explanation of these seeming marvels from one who has many times performed them all for the edification of his friends.—*Electricity.*

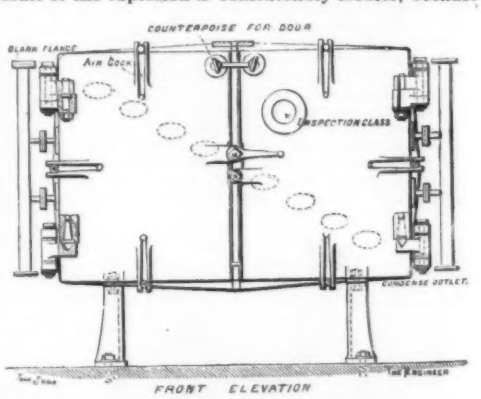
SAFETY APPARATUS FOR DRYING EXPLOSIVES IN VACUUM.

THE apparatus illustrated in the accompanying engravings for this purpose in an invention by Herr Emil Passburg, of Breslau, Germany, who thus describes it: Its purpose is the rapid drying of explosive matters, and the prevention of the danger and destruction to workmen, buildings, and machinery. Explosives are classed into three principal groups, according to the temperature at which they ignite and the violence with which the formation of gases takes place. (1) Impulsive explosives, which at a high temperature of ignition explode slowly; (2) explosives which at a high temper-



ature of ignition explode violently; (3) fulminate explosives, which ignite at a low temperature, and where the formation of gases takes place with the greatest violence and rapidity. At present the drying of the latter class only interests us, as on account of their nature they possess the greatest amount of danger.

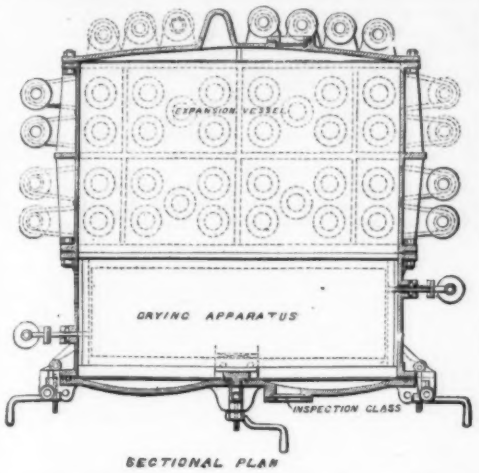
Experiments with these substances have given the following results: When placed in an iron vessel and exploded, the vessel was entirely destroyed and the fragments thrown with great force to a large distance. This explosion resulted in a very different way when the same quantity of fulminates was employed in a similar iron vessel, and when such vessel was exhausted and placed *in vacuo.* In this case, though a considerable pressure was exercised on the sides of the vessel, still the latter remained undamaged, though of course the vacuum was destroyed. Only after larger quantities of explosive matter had been used this vessel was at last destroyed, though what showed very remarkably, in a proportionately feebler manner. With a small quantity of the fulminate the vacuum in the moment of the explosion was destroyed, as shown by the vacuum meter, but at once again created on account of the condensation of the gases. From the above description one can easily find the explanation of the difference between an explosion in a vessel filled with atmospheric air and a vessel under vacuum. In the former, the sudden and violent pressure which is created by the expansion of the explosive gases is transmitted by the consequent compression of the air, which finally causes destructive results. If there is no air in the space in which the explosion takes place, the result of the explosion is considerably feebler, because



the gases can without hindrance expand in the evacuated space, and in the moment of their creation again rapidly condensing, while another transmitting body, as, for instance, the air, and its compression, with the consequent destruction, is avoided. Another cause of the weakening of the force of the explosion is that the evacuated space has first to be filled by the explosive gases before an inner pressure can be created on the sides of the vessel. With explosions of large quantities, notwithstanding the vacuum, such inner pressure on the sides of the drying chamber is created, and therefore on the apparatus Herr Passburg has provided a further safety arrangement, by which the gases can freely escape as soon as a pressure in the vacuum chamber exists. In the first place, the purpose of Herr Passburg's invention is to guarantee the absolute security of the working, but it also involves a more rapid drying. In this drying apparatus, where an explosion cannot do any damage, one can also work at a higher temperature, and obtain through this, with the assistance of the vacuum, a drying about twenty times quicker than after the old systems. On account of this rapid drying also only about a twentieth of the former quantities is now placed in the drying chambers, which again increases the safety, because the accumulation

of such considerable quantities of explosives in the different drying stations was always the source of the greatest danger. If such quantities in the old drying houses and other places of manufacture explode, it is doubtless that the destruction of life and property in a radius covering a number of miles will result.

The royal Prussian government has made the most exhaustive trials with the Passburg safety drying apparatus, and it is owing to these trials that its present



SECTIONAL PLAN

construction has resulted. For about a year a larger drying plant on the Passburg system has been working in the Royal Arsenals at Spandau, and has been specially tested as to its absolute security of working by creating artificial explosions, the results having been most satisfactory. In consequence, the Prussian Minister of War has adopted this drying apparatus for all fulminates made for the Prussian army. We are also informed that another government is erecting a drying plant after the Passburg system for the drying of the smokeless powder. In these cases the apparatus are of a modified construction, and of a larger size.

The apparatus consists of a closed iron vessel, which can be opened on one side by doors, easily running in their hinges. In this vessel are hollow horizontal shelves, which are heated by exhaust steam, as the engravings show. These shelves are placed one above each other, and the explosive matter that is to be dried is spread on trays, and then placed on these shelves Connected with this drying apparatus is the expansion vessel, which is provided with forty-four safety apertures. An air pump, also connected with this drying apparatus, creates a high vacuum in its interior, under which the water contained in the explosive matter evaporates very rapidly at a low temperature. The covers, which are loosely placed on the safety apertures, are provided with India rubber rings, and close absolutely air tight by the atmospheric pressure as soon as the vacuum is created. In a very short time the drying is finished; and by an alteration of valves, instead of exhaust steam cold water is sent through the heating shelves, cooling the explosive matter in the trays in a very few minutes, and it can then be taken out of the apparatus without any danger. Should an explosion occur the gases rush into the expansion vessel, the vacuum therein acting, so to speak, as a sort of absorbent of the force of the explosion. Should any over-pressure be created in the drier the forty-four covers on the safety apertures of the expansion vessel are thrown off, and the gases will find at once a free exit, losing their power thereby. The safety apertures are placed alternately, that the covers when thrown off cannot touch the necks of the apertures. The second engraving shows the ground plan, etc., of two drying apparatus connected with one air pump. That part of the room in which the expansion vessels are placed is divided from the part with the drying apparatus by a wooden partition, so that, in case of the covers being thrown off the safety apertures, the men attending the drying plant cannot be hurt.

DESIGN FOR A FIVE RATER.

THE design represented is not so much intended as an illustration of excellence in model as a novel and, perhaps, useful idea for a center board racing craft of any tonnage or rating. It will be observed that the center plate, heavy in itself, has a cigar-shaped piece of lead bolted on to its lower end in such a way as to take full advantage of the indulgence lately accorded by the Y. R. A. to the use of shifting ballast in this form. In presenting this illustration to the notice of our readers, we beg them to observe two things: first, that the arrangement carefully guards against that structural weakness upon which we have so often commented, and which the council of the Yacht Racing Association utterly ignored.

If any of our readers see merit in the plan presented here, they will bear in mind that the council were entirely ignorant of the contrivance, as we were ourselves at the time when they held their last meeting, and set their "little brief authority" in conflict with the superior judgment and knowledge of our most noted naval architects. This arrangement consists, as elsewhere described and illustrated, in the use of through bolts of practically unlimited strength, binding the two sides of the yacht together. In this way the *whole* of the ballast may be carried in and on the center plate. Need we point out that there is an advantage in this? If so, we may mention the fact that immense draught may be obtained when it is most required, *i. e.*, in strong winds, and small draught when it will be of advantage, *i. e.*, in light winds, and always in running. These two points alone are sufficient to secure the adoption of this contrivance. Secondly, we would draw attention to the fact that, by the use of this arrangement, the center plate can be taken out and scrubbed when so desired. This is a great point, in large yachts particularly. It obviates the necessity of having a wide slot and case, and the consequent continual drag of stagnant water therein.

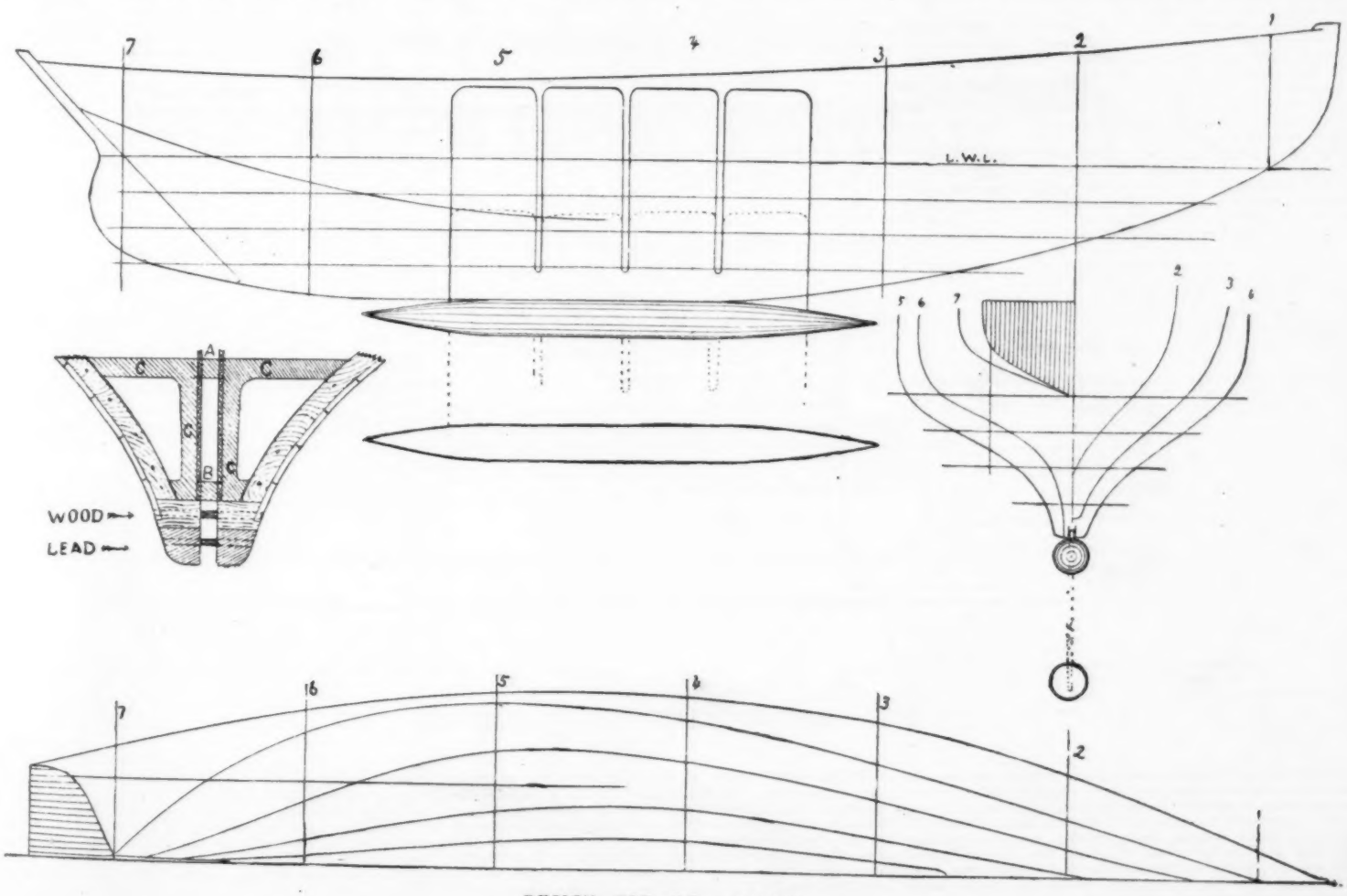
To clean the plate all that is necessary is to drop it out altogether, keeping, of course, the ends of the chains aboard, then haul the vessel clear into the desired berth, and when the tide has ebbed sufficiently, scrub both the plate and the yacht. In large vessels a dock will probably be required, and it may be necessary to perform the operation twice, so as to get at both sides of the plate. However, most yacht sailors will agree that this is preferable to carrying several tons of useless water. Critics may point out that such a yacht, so deprived of all her ballast, would upset! In answer we may say that we do not anticipate the carrying of the total ballast on the plate in *large* yachts, and in small craft a few pigs of iron would suffice to help them on an even keel during the brief space of time required.

As to the design, we have fixed the length of load line at 32 ft. We have no reason for doing so save that Windfall and Savourna are both longer, and Alwida and Glycera are both shorter. This might indeed lead to invariable defeat if everything depends upon the length on L. W. L., so that should anybody entertain this belief, and yet desire to build from the design, they will be able to do so by contracting or enlarging the spacing of the sections. The design has been hastily prepared by us more for the purpose of illustrating the peculiar form of center plate than through any conceit in the merits of the model. The plate is in this case intended to be gun metal 2 in. thick, and the lead bolted on to the bottom of it will weigh about 1 ton 7 cwt. The plate and the lead together will weigh somewhat over 3½ tons. This will leave a margin of about a ton for bolting on the wood keel. The drawing of the keel construction shows a through bolt in both the lead and the wood keel.

It will be observed that the flooring (C) here shown is one solid piece, securing both sides by the very substantial connections marked A and B. There will be three of these, and gun metal will be used in this case also. The slots in the center plate are intended to be 1½ in. wide, so that the flooring pieces may be 1 in. thick. It will be observed that they are bolted on the frames, as in the case of the ordinary keel boat angle iron floors. In addition, they have sides resting against the centerboard case. These may be secured to it by a small flange, if so desired. The object of thus supporting the case will be apparent when it is remembered that the leverage of both the plate and its lead have to be borne by the sides of the case.

We do not pretend that this design is excellent in any one particular, but we believe it will give a hint to those better qualified than we are to perfect the idea. Mechanism will have to be provided to lift the weight, but the very elastic phrase "manual power" will admit of many suitable contrivances for this purpose. There will have to be a chain both fore and aft, and these should be arranged in such a way as to work uniformly in raising or lowering the plate. Once this difficulty is surmounted, the only objection to the plan is the utter destruction of inside space. However, the craft has no pretensions to being anything other than a racing machine pure and simple, although we have no doubt that, if successful, she would gain many admirers ready to swear to the fact that she is "the finest little cruiser in the water."

The displacement (calculated from a ½ in. drawing) of the design is 7 tons 17 cwt., and the center of buoy-



DESIGN FOR C.B. 5-RATER.

Scale ½ in. = 1 ft.

ancy is 17 ft. 10¼ in. abaft the stem on L. W. L. This is exclusive of the lead on the center plate.

The following is a table of offsets:

Half breadths.	1 ft. in.	2 ft. in.	3 ft. in.	4 ft. in.	5 ft. in.	6 ft. in.	7 ft. in.
Deck	0 9½	2 10½	4 3	4 10½	4 11	4 4	3 2½
L. W. L.	—	1 7½	3 1	4 2½	3 7½	3 8½	0 1½
No. 2 W. L.	—	0 9½	2 0½	3 0½	3 3	1 9	—
No. 3 W. L.	—	0 1½	1 0	1 8½	1 7	0 8	—
No. 4 W. L.	—	—	0 4½	0 9½	0 9	0 2½	—
L. W. L. to deck	3 8½	3 1½	2 8½	2 4½	2 2½	2 2½	2 5½
L. W. L. to keel	—	2 1½	3 4½	3 11	3 11	3 10	—

The water lines are 1 ft. apart, and the sections 5 ft. 4 in.—*The Yachtsman.*

CHICAGO ELEVATED RAILROAD.

THE city of Chicago has increased vastly in size of late years, and has spread out on all sides, save that of the lake; and since the city limits have been extended, the enlarged area has been rapidly filling with population, a district 24 miles long by 15 in width, so that a necessity has arisen for rapid transit, which can furnish those coming from distant points a quicker service and fewer stops than on the surface lines. It was to partially supply this accommodation that the South Side Rapid Company, of Chicago, commenced preliminary work in 1888, by securing a right of way 25 ft. wide (by purchase or condemnation if needed) at the rear of lots, and alongside alleys, over the distance extending from Congress to Thirty-ninth Street, a little less than four miles, in a straight line. A matter of great importance in connection with this right of way is that with it is conveyed a perpetual right and freedom from all damage suits attending the construction and operation.

The foundations of the viaduct average about 10 ft. deep, resting on a clay bottom. A concrete bed is formed 1 ft. thick by 7 ft. square, on which two stones are placed, each 2½ ft. and 5½ ft., which hold the anchor bolts and distribute the weight over the concrete. From this foundation a brick pier rises, 5 ft. square at the base and 4 ft. at the top, and 3½ ft. high. A bluestone cap 3½ ft. square and 1 ft. thick completes the foundation, and supports a cast iron base, weighing 1,800 lb., in which the columns stand, and are held in place by the anchor bolts, which are 1¼ in. in diameter and 5 ft. in length. There are two sockets, 21½ in. deep, in this iron bedplate, which receive the two channels that compose the sides of the column, and all remaining space is filled with a mixture of iron filings and sal ammoniac. The lateral distance from center to center of columns is 12 ft., except at stations, where they are spread to a distance of 19 ft. 9 in., to allow the longitudinal girders to rest on the transverse girders and to make room for the station building. The longitudinal space between columns varies from 35 ft. to 60 ft., but in most cases it is 45 ft. Plate girders are employed throughout; the flanges are made of angle iron 4 in. by 6 in. by ⅞ in.; the webs of the longer girders being 6 in. by 6 in. by ⅞ in.; the web plate is ⅜ in. to 7/16 in. thick, united to the chord angles by ⅞ in. rivets placed from 4 in. to 6 in. apart.

These girders are intended to sustain a moving load of 1,000 lb. per lineal foot per girder, and a dead load of 370 lb., which gives a working strength of about 1,300 lb. per lineal foot per girder, with a large factor of safety; the flanges will not be strained more than 10,000 lb. per square inch by the equipment to be used, but all the material has been actually tested to upward of 30,000 lb. per square inch as the elastic limit before being accepted; while the tests show an ultimate or breaking strength of fully 50,000 lb. per square inch.

The girders, as said, vary from 35 ft. to 60 ft. in length, according to the spaces between columns; the shorter girders are 42 in. deep and weigh 7,000 lb.; the girders, 50 ft. long, are 48 in. deep, and the 60 ft. girders are 54 in. deep, and weigh about 9,000 lb. The girders are secured to the top of the columns by bolts and rivets ⅞ in. in diameter, and at every other span there are slotted holes in the lower chord of the longitudinal girder, permitting of free expansion and contraction; the girders are connected by a system of lateral bracing riveted to the flanges both at top and bottom. Angle irons 4 in. by 4 in. also stiffen the girders vertically at intervals of 5 ft. and prevent buckling. There will not be more than 1,800 lb. to 2,000 lb. pressure per square foot on the soil under the concrete; and the clay bed, which was found at the depth of only 10 ft., is excellent and firm.

From the ground level to the bottom of girders is not less than 16 ft., and to the rails 20 ft.; where the road crosses a line of rails at Sixteenth Street, the clear headway is 20 ft. from the track; at Twelfth Street a viaduct is crossed, and to accomplish this, 1,000 ft. distant from either approach, a grade is commenced with a rise of 26 ft. to the mile.

The columns are constructed of 15 in. channel bars weighing 50 lb. to the foot, braced by a system of flat iron braces 4 in. by ½ in.; they are 15 in. square up to within 3 ft. of the top, when they gradually broaden out, forming a spread top, on which are carried the ends of the longitudinal girders.

The longitudinal girders carry the track superstructure, the ties of which are hardwood 6 in. by 8 in. and spaced 20 in. apart from center to center; they are held to the girders by hook bolts instead of being rigidly bolted to them, thus permitting the expansion of the girders apart from the track. The steel rails, weighing 90 lb. to the yard, rest on these ties, the rail joints being what are known as the "Fisher" bridge joint, which trusses the base of the rail and gives a uniformly even surface to the tread of the wheel in passing the joint, both rail ends deflecting the same distance at the same time, preventing any pounding. Joints are broken and the ends of the rails rest on an arched beam between the ties; it is thus a supported joint, and the load comes upon the two shoulder ties, directly under the rail ends; the rails are spiked to the ties with spikes 5½ in. by 7/16 in. A guard timber, 6 in. wide by 8 in. high, is bolted to the ties on each side; this would effectually prevent derailment should wheel or axle break by any accident; these guards also serve the purpose of longitudinal bracing, and receiving the thrusting force coming on the rails by breaking, distribute it over many spans in length, and no better way could be devised for stiffening the track longitudinally. Ties 6 in. square are placed between the tracks, and on them four planks 2 in. thick by 6 in. wide furnish a walk for employes, extending the entire length of the road, and should blockade or delay occur, passengers could proceed to the nearest station without difficulty.

The stations are very conveniently arranged for their

Fig. 1.

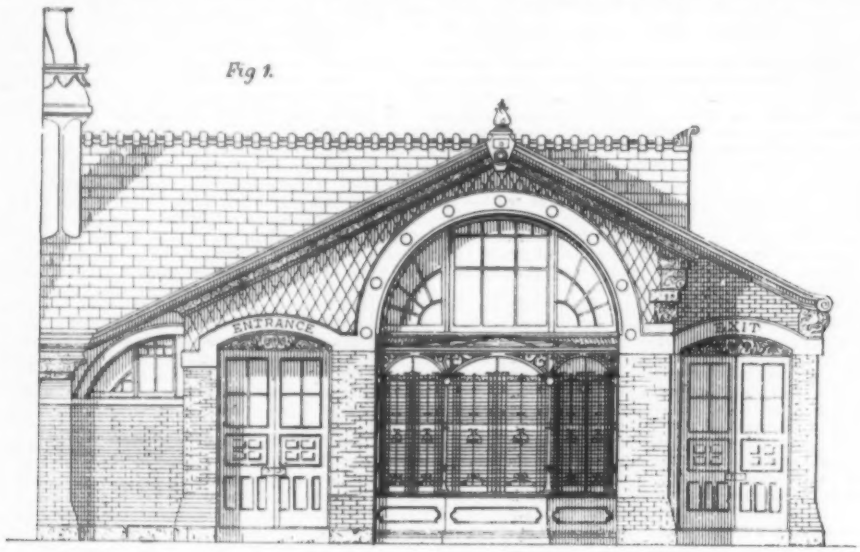


Fig. 2. Cross Section of Platforms

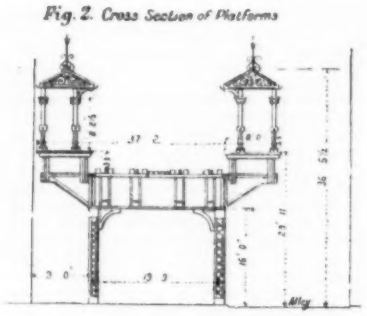


Fig. 3

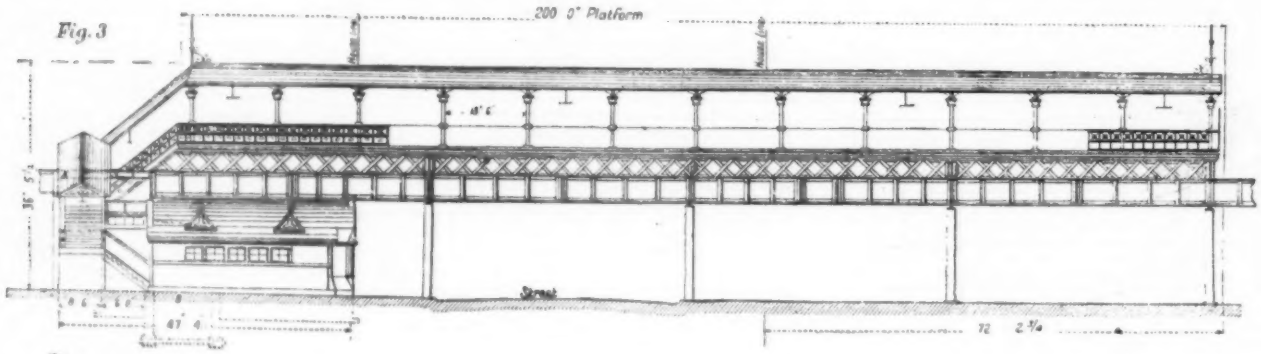
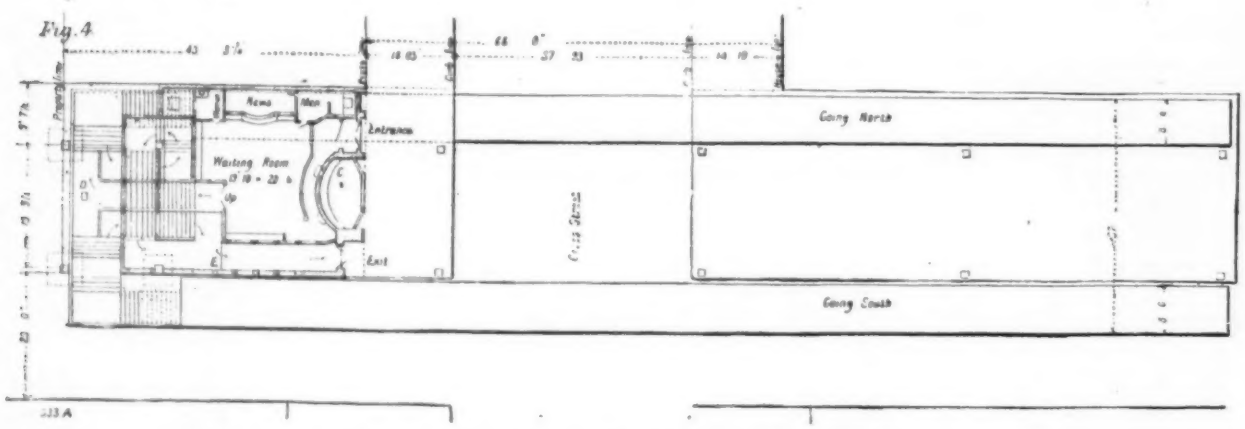


Fig. 4



THE CHICAGO ELEVATED RAILROAD.

purpose, and, contrary to usual custom in American elevated roads, they are built on the ground underneath the railway. Every station has one entrance and one exit. An electric bell sounds automatically as a train from either end approaches within 500 ft. of the station, indicating the direction in which it is going.

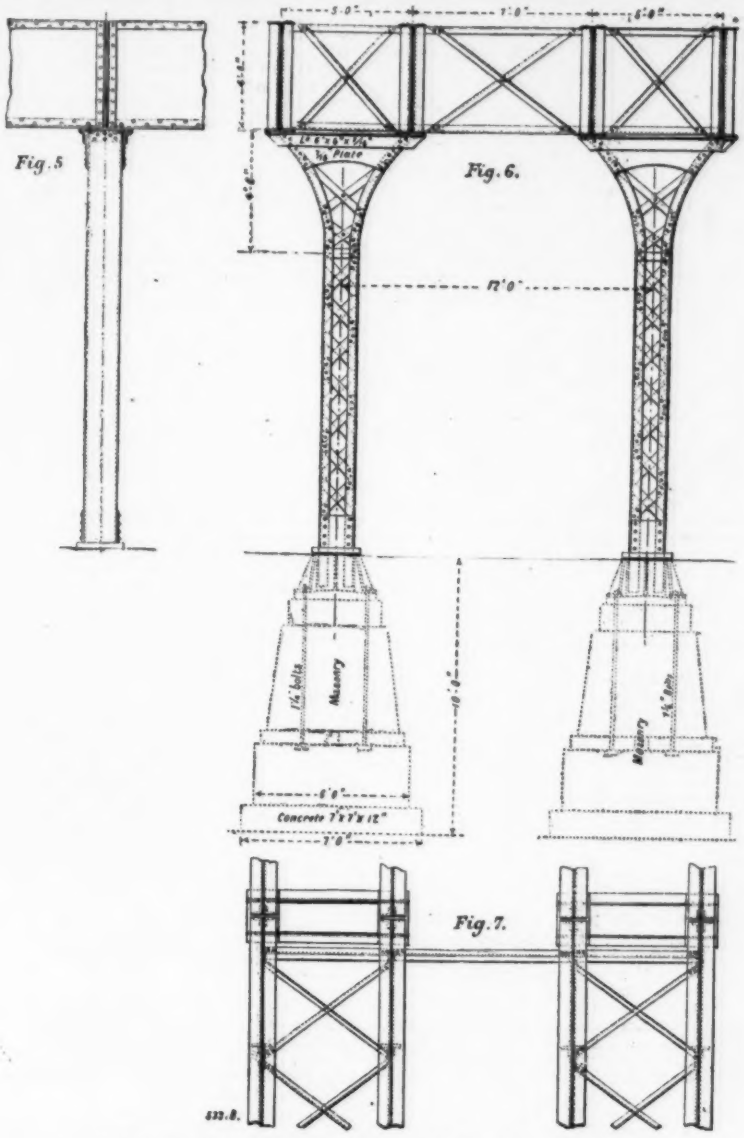


Fig. 5

Fig. 6.

Fig. 7.

THE CHICAGO ELEVATED RAILROAD.

Passengers having already obtained their tickets in the waiting room, deposit them at the foot of one of the stairs leading to the platforms above, one for the north, and the other for the south, bound trains.

The platforms, which are ample, being no less than 200 ft. in length by 8 ft. wide, will accommodate a train of six cars. These platforms are on the outside of either track, and will be illuminated at night with arc lights. The distance between stations varies from three to six blocks, according to the population and importance of the cross streets.

The road is a continuous straight line without exception from end to end; it will soon be extended four miles further south, branching to the World's Fair on the east, and to the rapidly increasing district of Englewood to the west. Trains will be run at very short intervals, and the fare be 5 cents. The equipment will be similar in general design to that on the New York and Brooklyn elevated roads, with many improvements suggested by their experience, and they will be constructed and furnished in the best possible manner to avoid unnecessary noise, and secure comfort and convenience to passengers.

On Colonel C. Goddard, of Chicago, has rested the entirement management and direction of the work connected with this railroad, Mr. R. J. Sloan assisting him as chief engineer.—*Engineering*.

BICYCLE RACING ARRANGEMENT.

THE annexed cut illustrates a stationary racing machine manufactured by Ernst Strecker and Dame in Magdeburg, Germany, and designed to accommodate bicyclists bent on racing in unfavorable weather.

The machine is provided with two training bicycles mounted on a fixed frame and arranged one alongside the other.

Each bicycle is at its rear wheel in frictional contact with a pulley connected with and actuating a transmitting device operating a pointer on a dial facing the riders.

The two pointers of the two bicycles indicate on the same dial and move independent of each other, and according to the speed given to the wheels by the riders; the faster moving pointer signaling the victor.

The transmission is so proportioned that a full revolution of either pointer corresponds to a ride of a mile. —*T. G. H.*

BICYCLE RACING ARRANGEMENT.

THE MAN OF SCIENCE—HIS METHODS AND HIS WORK.*

By R. H. THURSTON.

INTRODUCTION.

Ladies and Gentlemen and Members of the Sigma Xi:

In appearing before a society of men of science, and especially before an association having such grand purpose and noble aims, the first duty of your orator is to acknowledge the compliment paid him in the invitation extended him on this occasion to present his best thoughts to so intellectual an audience, and to make an apology for their inadequacy to the occasion. The first may be made most heartily and unhesitatingly; the second would seem to demand a better reason than that which alone must be allowed: the brief time available for preparation, the very great pressure of work, and the unintermitted succession of duties compressed into the closing weeks of the college year.

But while I am sure that you cannot fully realize this gratification, and the appreciation of the honor which is its source, that my words would, if possible, indicate, I am sure, also, that you will receive with friendly criticism and all charity what must represent my best endeavor under such exceptional and unusually unfavorable circumstances. That what I have to say is not fully up to the standard that I am sure we should all desire to see maintained at these annual meetings of members of a society pre-eminently devoted to high thinking, and peculiarly appreciative of great and fruitful thought and work, must be attributed to these adverse conditions, as well as to the fact that your chosen orator is neither philosopher, scholar, nor rhetorician. Frankness and honesty must make amends for all.

A word as to the character and aims of Sigma Xi. As I understand the formulated platform of our order, it declares our purpose to be the building up of a fraternity of the lovers of scientific truth, lovers of all the knowledge coming to us out of nature; an association of students, of investigators, by exact and scientific methods of research, of all the phenomena of the seen universe. It seeks, at the same time, to furnish a nucleus about which to gather lovers of science for the sake of science and its works; to give testimony of appreciation of good work performed by young men and women, devotees of science; to establish a brotherhood—which, grammatically and naturally, embraces a sisterhood—of all engaged fruitfully in a common task and having a common purpose; to encourage original research; to promote the scientific spirit, scientific knowledge, scientific investigation in all known fields. We aim at, and hope to achieve, the foundation of a great fraternity that shall grow in numbers, strength, power for good, leading, in this country, at least, perhaps in all the world, the grandest scientific movements of coming times. The acorn is planted; its first tender sprays are coming into view; our successors, as we all hope, and with confidence, shall see a mightier oak of this variety than ever yet grew.

Such being the character and the purpose of our fraternity, I am sure I shall be justified in the selection of my theme; the methods and the work of our ideal type and representative, the true man of science.

In this discussion I desire to restrict myself mainly to the man with whom we are most familiar, while fully recognizing the fact that the man of science, in a true and liberal sense, is to be found far outside the range of our own special field. We do not *admit*, we *claim*, that Sir William Hamilton, the logician, Sir William Hamilton, the mathematician, was doubly a man of science, that Lord Bacon was as much a man of science as was Newton; that the framer of a code of law or of philosophy may be as much a man of science as the seeker among the stars; that we have among us the scientific lawyer, the scientific engineer, the scientific student of Fichte and Hegel and Compte and of Kant, as well as of Descartes, of Darwin, or of Spencer or of Herschel. He is a man of science who loves truth for truth's sake, and who also seeks to know and to learn all the facts and principles that are recognizable by the human faculties in whatever realm of the seen or the unseen, the known, the unknown, or the possibly knowable, they may exist. Absolute integrity of intellect and judgment, combined with an inextinguishable desire to know the right by right ways, are the characteristics of all this class. They are found living, and working, and seeking knowledge in every department of human activity and of natural existence. To all such men we owe equal respect and equal honor. The seeker of truths, whether in the fields, or in the mine, in the pulpit, or on the bench, whether following Aristotle or Bacon, or Newton or Darwin, or the minutest or the grandest lights of the human mind, may be a man of science, and *will* be one, if true to himself and the right.

THE MAN OF SCIENCE—HIS METHODS AND HIS WORK.

The characteristics of the man of science, as I would define them, are to be found in the emotional and the moral, as well as in the intellectual aspects of his personality. He is distinguished by a love of nature and all her works, a love of learning for its own sake, a love of scientific methods and scientific work in research as intrinsically attractive, as well as a means to an end. He is characterized, in the ideal type at least, by an absolute conscientiousness, infinite courage, and invincible persistence, with a perfect faith in the complete accordance of all truths, and entire indifference as to what truths shall prove to be, so they be truths. His intellectual and specific qualities are

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prompt and certain recognition of facts and principles; ready perception of the relations of facts to law, and of laws to sciences; a genius and an inventive talent for planning researches leading to the discovery of new truths through a knowledge of the facts and laws which comprehend old ones; power of production of purposeful plans, and of steady, never-discouraged, systematic work in carrying them into effect; ability to direct every available means to the one exactly conceived and formulated plan; turning to his own purposes every resource of contemporary knowledge and art. Any one of these classes of talent, whether moral, intellectual or emotional, being non-existent or lost, the man of science fails of perfect development.

Who but an Agassiz, loving nature as he loved his God, affected by the sight of an Alpine peak, of a river of ice, of the swelling waves of the ocean, loving his task as the boy loves his sports, but with a graver and steadier love, as the love of a patriarch for the gray haired companion of his life exceeds the love of the boy for his chosen partner, loving the pursuit of knowledge as the dearest task the world could assign him—what man but such as he could ever truly typify the scientific man? Who but a Bruno, loving truth more than life, trusting to nature more than to dogma, dying at the stake for man's knowledge, as opposed to man's beliefs, for God's law in opposition to the commands of the church, could represent the lover of knowledge, the real scientific spirit? Who but a Faraday, absorbed in the pursuit of the great truths revealed only to such an indefatigable investigator, devoting time, thought, life, and all his powers to a defined research, could have earned the fame that his work in electro-magnetism gained for the most modest of men, even though the inspiration of a Davy should exert its noblest influence upon him? Who but the loving seekers of truth for truth's own sake, amorous of her every charm, yet ascetic to the last degree, all-loving, self-giving, ready to die, as did many a man in earlier days, for her sake—who but such as these could stand as our ideal of the scientific man, with an emotional soul as his primary characteristic?

What were science, or the scientific man, without the moral qualities? What without conscientiousness, courage, faith, confidence on the part of the man would be the state or the standing of science. Had not every now famous member of this most royal of castes possessed the attributes so well stated by Clerk Maxwell, "Concentration of effort in seeking to identify the apparently different forces of nature, far-sightedness in selecting subjects for investigation, persistence in working out the results of his discoveries, and accuracy and completeness in making his final statement of the laws of the phenomenon:" had he not possessed all these qualities, what possible claim could he have earned to memory and fame? These characteristics of the scientific spirit must mark, and must permeate, every minutest portion of his work.

Without absolute conscientiousness, how could the chemist analyze the organic compounds? Without invincible courage, how could a Davy, or a Stephenson, devise and prove a safety lamp? Without a perfect confidence in the ultimate justification of law by apparently conflicting laws, how could astronomer or geologist proclaim the true motion of the spheres, or the measureless life of a slowly forming universe? How could any man of science, without inextinguishable belief in the ultimate reconciliation of all truths, stand before the mysteries and the wonders of the universe, and retain religious faith, intellectual poise, or even sanity? Without entire indifference as to the form that the outcome of his work shall ultimately take, so it be right, how could any investigator carry on his work without wavering or quailing?

The absolute sincerity and absolute truth of the scientific man is his grandest and bravest characteristic. "Speak what you think, now, in hard words, and to-morrow what to-morrow thinks in hard words again, though it contradict everything you said to-day." When a man seeks truth, with all his soul, Consistency may be trusted to take care of herself. Without this quality no devout astronomer could pursue his calling, facing a thousand possible contradictions of his creed; lacking this, no intelligent geologist could read the Scriptures and continue his study of the growth of primary, secondary, tertiary and quaternary worlds. Failing here, the work of a Darwin, the researches of a Spencer, the investigations of a Tyndall or of a Huggins must all fail of their highest ends. The one and only question that the really scientific mind allows itself to seriously consider, first and above all else, is: What are the facts? And it is in the endeavor to learn exact truths that the laws enunciated and proved by a Newton are made to reveal the structure of solar and stellar systems; that the spectroscopist learns to read the constitution of the farthest stars; that the geologist seeks to ascertain the history and the chronology of the worlds; that the chemist tears apart the molecules and the atoms and recombines them in a thousand forms to find the secret of the Great Builder of the seen universe; that the physicist seeks the sources of light without heat and of heat without light, and of the electric forces, in every corner of the vast, the infinite arcanum, in animate as in inanimate nature, and looks to glow-worm, fire fly, gymnotus and torpedo, and fossil gum, and even invades the sacred precincts of the human body in his search for new facts.

Again, "the restraining grace of common sense is the mark of all the valid minds—of Æsop, Aristotle, Alfred, Luther, Shakespeare, Cervantes, Franklin."

Self-poise and a good judgment, with keenness of perception, breadth of view, and promptness of decision, all essentials of a real "common sense," are as much the characteristics of the scientific investigator and of the philosopher searching out the ways of the Maker, as of the man of business or of the thrifty housekeeper. This is the ballast required in any vocation, as in every over-sea voyaging craft. Without it the brightest minds may yaw and jibe, and drift far off the course, and may even fail to reach a haven at all. Goethe, in his early days, was taught this lesson, or we should never have known the grandeur and the might of his powers; Shakespeare, before Sir Thomas Lucy, made to plead for mercy, learned this lesson, or we should never have learned the noblest lessons of scientific construction of the drama, of deepest insight into human life and human passion. Franklin, alike great in science of nature, in science of the arts, in science of government, was the very concentration and essence of common sense. Washington, scientific engineer, scientific strategist and soldier, scientific in the execution of his highest trust, exhibited the steadiness, the absolute reliability, every day of his life, that comes first and most of common sense. All modern work in science, whatever its department, stands upon a foundation of common sense method and of simple, straightforward application of previously acquired knowledge. Such is the man of science and such his ways, if he be really of our guild; such must be our ways if we be worthy of his comradeship.

"Teach me your mood, O patient stars!
Who climb, each night, the ancient sky."

His is the mood of the stars: "*Ohne hast, ohne rast, wie die sterne*," he moves on steadily, quietly, confidently, toward an end and aim which he has distinctly and carefully determined, accomplishing his self-appointed task by the constant application of all these essential qualities of the conqueror of a mightier world than Alexander dreamed of. He does not know, nor does he concern himself, whether dangers, difficulties, herculean labors, lie in his way; over all and through all his patient, persistent, determined course is laid, and the great purpose is consummated, as is that of the sailor crossing fitful seas, despite calms, gales, fogs, rains, snows, icebergs, or reefs, dangers of wreck from earth, air, sea, or fire. If he goes by his chart, steers by his compass, takes regular observations, and makes exact computations of latitude and longitude, he will surely reach his port. The moods of the man of science are strong and steady, his ways are charted with sure insight and foresight; his methods are those of strategist, logician, and statistician; and his spirit is as determined as that of the followers of Cortez, as truth-loving as that of a Savonarola, as aspiring and as self-denying as that of a Livingstone; in all respects as worthy of divinity as human powers permit. Such, at least, is our ideal and our type, and to this we may all aspire and all incline; however far short of attainment we may finally reach. This is an ideal to which we may all and always cling.

Next in order, we ask, What is the *work* of the man of science? What is he to do; and, in the past, what has he done?

"What has he done? is the divine question which searches men and transpierces every false reputation." If what he has done proves him to "know the laws of nature better than other men, his nation cannot spare him." If he "inhabits a higher sphere of thought, into which other men rise with labor and difficulty," and has but to open his eyes to see things in a true light, and in large relations, he is a great man, but he is great because of what is in him:

"Deep in the man sits fast his fate,
To mould his fortunes, mean or great."

And as of the individual, so of the class of which he is a member.

What, we would now ask, is the work of the scientific man as we conceive him? What is his aim? What is his final reward?

The work of the man of science, as I understand it, and I now restrict myself to the modern and narrower, and, to us, more personal sense of the word—the work of the scientific man dealing with the natural sciences, so called, is, in grandest outline, the revelation of the facts, laws, operations of nature, of the plan of the universe, so far as the universe is composed of matter and moved by the forces affecting that matter, and still more, the construction of the formulas which constitute the code of that natural law. This, perhaps, more accurately speaking, is the work of scientific men. The work of the individual is either to discover and record new facts, to reveal new laws, to collate and build upon the discoveries of earlier workers, combining the products of separated and perhaps of discontinuous sections into smoothly connected areas, or to find new and useful applications of known facts and principles for the benefit of his fellows. The aim of science is twofold: To produce a pantology, as an intellectual and noble achievement, glorious in itself; and to make knowledge useful and helpful to the race. The early Greeks glorified the worker in the first of these fields; the modern world gives tribute and pays honor to both.

This work is his because he loves it. Says Ruskin: "Fix this in your mind as the guiding principle of all right, practical labor, and course of all healthful energy: That your art is to be the praise of something that you love. It may be the praise of a shell or a stone; it may be the praise of a hero; it may be the praise of God; your rank as a living creature is determined by the height and breadth of your love."

If we are scientific men, "all that we do, we do in kingly fashion; we let tongues wag as they will; what we see to be the right thing, that thing we do." But we do it after the methods of the art which is ours. We observe "the difference between similar and same;" we not only love, we labor; we not only labor, we wait, if needs be. Our love for our art impels us to seek, with righteous curiosity, the solution of a problem in the mystery of existence of which we are a part. Our science and the spirit which it promotes impels the seeker to move as a great strategist moves in war time. We are first to make sure of our base; looking far and near for certainty of our ground; then we plan the advance, carefully, completely, leaving no possible visible line unexplored; we study alternatives as the chess player traces out the threads and teaches himself to follow the intertwisted net of advance and retreat, in his most masterly of the games of peace and leisure. The plan complete—always, as in any other serious campaign, subject to revision in the light of later knowledge and more complete information—we proceed to our exploration of the hitherto unknown field.

The method of the man of science, therefore, is:

First, to study the "state of the art," in the department chosen for exploration. He reads the accounts of earlier work by those who have preceded him, in chronological order preferably, and verifies their statements and repeats their processes if necessary. In this he follows Gautier's advice, who says:

"Always go to the source. Take no man's authority, least of all mine. Verify every reference; keep an exact record of everything that you observe. Compare every statement that you find in your books with the original authorities. Be content to hold your judgment in suspense if you have no original source upon which you can base an opinion; and remember that the original source is in all cases the court of last appeal."

This process of historical investigation, precedent to his own entrance into the field in research, gives the student a knowledge of already discovered facts, enables him to avoid the expenditure of time, patience, labor, in repetition, uselessly, of earlier investigations, and permits him to see clearly just where his own work must begin. It gives him a basis on which to build, teaches him what uncertainties of past completed work remain to be removed by further examination before attempting to advance; what dangers of insecure lines of communication behind him must be removed; what line may be safely and conveniently occupied in organizing for his forward march.

Secondly, the purpose and direction of the advance is to be considered. The objective point may be obvious and visible and may only require to be connected with conquered territory by well settled lines, and then free communication secured; or it may be that certain lines have been traced to a known point and their convergence may evidently lead to some unquestionably important but undefined grand center of natural phenomena, a ganglion in the nervous system of the universe, or, again, a boundary may have been reached and a desert may seem to give no promise and offer no potentiality of further gain by extension of our lines. But in either case, eternal curiosity, no less than eternal sense of the duty of leaving no known limit permanent, no hitherto unknown field unexplored, no possibility uninvestigated, allows no cessation of the self-imposed task. The visible point must be connected by exact and sure triangulation and by continuous lines with the area about us; the segmental sections and their untraced lines must be made complete; and the seemingly unfruitful desert must be explored and passed, that every undiscovered treasure, if such be existent, may be acquired.

Finally, the territories conquered from the unknown are to be minutely studied in every minutest part, mapped, reduced to measure, and permanently placed in the list of the accessible and actually known.

The simplest illustrations of the methods and processes of science are seen, perhaps, in the field of physical investigation, both in the construction of the science and in the minor work of detail in investigation. By the methods just outlined, in partial metonymy, the physicist, seeking the "light of a future," searches the records of the past, finds scattered facts and laws bearing upon his problem, sums up the state of the art to his own time, arranges facts and laws into as nearly a complete and consistent scheme as possible, finds that much has been done, that the general outline of a science has been constructed, that the processes involved in transfer of light, as of heat, are well known, but that the ways and means of transportation of energy into light, into heat, into any specified form of ether vibration, have not yet been all discovered. His own problem is identified and enunciated at once. It is for him to seek ways of compelling ether vibration of certain exactly stated rate and amplitude. Next he discovers that this is certainly possible; every jet of alcohol flame in his laboratory, every firefly circling over his lawn in a summer evening, proves the fact. Now he calls every resource of spectroscopy, of chemistry, of physiology even, to his aid, and seeks the road to the visible but hitherto inaccessible point. His historical research precedes the construction of his plan of physical investigation; his scheme comprehends all that can be compelled to illuminate his path, to give a clew to secret ways, or to indicate previously unsuspected applications of scientific principles to this case. Sooner or later, he is sure to reach his goal. Such are the methods of science, and such their applications. It is thus that the world has been enlightened, that a vastly greater progress has been made in a few recent centuries than in ages before.

Glance over the field and note how completely the knowledge of our own time, the positive knowledge—which mainly comprises the fruit of scientific investigation—has come of the work of two centuries. Read the chronologies and observe how the records of science, literature, and art gradually come in to displace the minor notes of rise and fall of dynasties, of births and deaths of kings, as we pass onward from the beginning of the seventeenth century; how the date of publication of a great author's works comes to supersede the record of political and diplomatic follies; how the inventor and the man of science assume nobler and nobler proportions, as benefactors of mankind, as we approach the nineteenth century. This, being interpreted, means simply that scientific methods and scientific work, unknown in earlier times, as was the product of their exercise, have gradually come into the world to perform their grand task of renovation, reconstruction, erection of new worlds on the decayed structures of the middle ages.

In the sixteenth century we find Spenser's Faerie Queen and Lord Bacon's Essays—not one scientific treatise other than philosophic; but even one work is a finger post pointing out all modern ways. Many works of faith, numberless editions of the Scriptures; but not a treatise of fact, no great treatise on science, no science created.

The seventeenth century opens with the martyrdom of that great representative of our guild, Giordano Bruno. The event constitutes an exclamation point, the mark of an historic, of a catastrophic event in the life of the race. The very same year, 1600, saw the publication of that classic, Gilbert's *De Magnete*. Chapman's Homer and Bacon's Advancement of Learning came in together in 1603-5, and the *Novum Organum* later. Galileo and Shakespeare closed their lives and did their work in this century—facts of mightier import than the death of Queen Elizabeth, by far. Tycho Brahe and Fabricius lived then; Kepler made his computations of the orbits, Harvey discovered the cycles of blood circulation; Boyle published his in some respects most remarkable, perhaps, of all works on physics; Milton lived, pleaded for another education and died, famous for his great poem, but even more entitled to honor for his vision of a modern method of scientific education in the arts as well as in the humanities.

Cromwell was born and the Taj Mahal was built; but the brightness of the day which saw Harvard College founded, or that which gave opportunity to observe for the first time the transit of Venus, far eclipsed even

those notable dates. Racine died, but Descartes and Newton were born; Richelieu died, but Pascal lived; and William Penn and Leibnitz were his contemporaries. Holland was wasted by the sea; but Von Guericke invented the air pump and Huyghens discovered a satellite of Saturn, the *Journal des Savants* was issued, and the Royal Society was founded. The peace of Westphalia was signalized in the year 1648, but Pascal demonstrated the fact of the pressure of an atmosphere in the same year, thus made vastly more notable. The patent for Carolina was given in 1663; but the year is famous as that in which Worcester invented his steam engine, in which coins were first made in England, in which the Academy of Inscriptions was founded in Paris. Only a year later, Newton announced the binomial theorem, a grander event than the signing of the treaty of peace between the French and the Pope. Rembrandt died in 1669; but Brandt discovered phosphorus, and Newton invented the reflecting telescope.

In this century Roemer marked the velocity of light, and Greenwich Observatory, the mightiest implement of modern astronomy, was organized; Leibnitz invented the calculus; Locke's Essay and the *Dictionnaire de l'Academie* were printed. The seventeenth century may indeed be considered as the date of the birth of modern science, after an embryonic period extending indefinitely into the earlier past. The death of Bruno marked the entrance into visible life of this modern Hercules, and the rapidity of growth of his mighty and wondrous powers may well startle and amaze the world.

In the eighteenth century, the child, supposed mature at its opening, if not Minerva-like in its entrance upon the scene, gives some idea of its capabilities, of its even now inconceivable powers and mission. The century was crowded with great events, in the presence of which wars and rumors of war, political changes, lives and deaths of princes, sink into insignificance. Frederick the Great and Louis XIV., Czar Peter and Napoleon, made the world uneasy; the French and the American revolutions marked grandest political movements; Charles XII. invaded Russia, and campaigns, sieges, and naval battles were never-failing causes of interruption of the greater works of peace. But it was in this century that Boscovitch was born, and Buffon, Euler, Haller, D'Alembert, Adam Smith, Priestley, Lagrange, Watt, Galvani, Lavoisier, Volta, Laplace, Dalton, Fichte, Humboldt, Hegel, Ricardo, Davy and Gay Lussac, Oersted and Berzelius, George Stephenson, Fulton, and Evans and Stevens. Marvelous list of "honor men."

This same century gave us the voltaic pile, and Newcomen's steam engine, the first real heat engine, properly so called. Newton wrote his Optics and discovered the composite character of light. Franklin was born and Linnæus gave us his "philosophic botany" while the American sage was proving the identity of electricity with lightning. The patent law was established, and Invention began her noble, beneficent, and wonder-working career. Dolland made the achromatic objective; Watt began his numberless improvements on the steam engine, giving the world its mightiest servant and most docile slave. Carbonic acid and oxygen, and hydrogen, were discovered. The outer planets were brought into view; the balloon became a new source of danger; while Jenner began his work of saving millions of human beings by vaccination. The germ of the telegraph was found; the hydraulic press was invented; the lithograph produced. The century was fittingly closed by the publication of Laplace's *Mecanique Céleste* and of Count Rumford's proof of identity of heat and dynamic energy.

In the seventeenth century, the seed began to germinate; in the eighteenth, it began to flower; in the nineteenth, we have seen a harvest reaped that we may well believe will prove the least and earliest of many, and constantly growing, centennial fruitages. What a list of marvels have been seen by our parents and ourselves! My father was born in the year 1800. When a child at his mother's knee the science of chemistry, given a new life and purpose by Lavoisier, was supplied with form and furnished foundations by the announcement of the atomic theory by Dalton (1803); a school boy of eleven years, he read of the completion of the Bell Rock lighthouse, the beacon directing later engineers, and the foundation of Stevenson's fame; at twelve he read of the discovery of iodine and its related elements; a year later, of Sir Humphry Davy's discovery of the electric arc and his correctness of Rumford's thermodynamic discovery, and a little later of the invention of the Davy and Stephenson safety lamps. At seven he shared the wonder of his parents when told of the voyage of Fulton's Clermont from New York to Albany, without wind or sail to aid, at the wonderful speed of five miles an hour, and was astonished to learn, on pursuing his inquiries, that, for twenty years, inventors had been more or less successfully striving with the problem of reducing the steam giant to service on the water, as Watt and his contemporaries had on land. At fourteen, the boy learned that George Stephenson had succeeded where, five years earlier, Trevithick had failed, and had made a steam carriage capable of drawing wagons and carriages filled with passengers on the long existing railways or tramways of the North of England, and he watched with breathless interest the progress of that grand invention until he saw its final success assured by the Rainhill competition of 1829.

At nineteen, he was interested in Macadam's plan of converting roads of dust and mud into good surfaces for vehicles to traverse; but he was roused to highest enthusiasm by the reports of Oersted's discovery of that—strange as it may seem—still mysterious phenomenon, electro-magnetism. In 1821, he built his first steam engine, with hammer and chisel, and a rude foot lathe, without a planer, and utilizing the water power of the home farm stream. A little later, he built a "sectional," or "safety" water tube boiler, following exactly the principles first enunciated so precisely by John Stevens, twenty years before, and then heartily wished that he might secure the services of Babbage and his marvelous, more than human, calculating engine (1822), in making his various professional computations. It was about this date that he made, with a brother equally interested and enthusiastic over the possibilities of steam power, one of the earliest steamboat voyages through Long Island Sound, from Newport to New York, only to find that Fulton and Stevens, and Livingston, and the Vanderbilts, were gathering in the lines of commerce and fortune that they had dreamed were free to them. In the three quarters of a century that he lived and worked—for he fought the good fight and did his appointed work from early boyhood to the day which brought his last illness—in a single lifetime, this man saw the grandest development of modern times. He saw the growth of the whole system of textile manufactures, of the applications of steam to all its myriad labors, the building of the steamship, the invention of the locomotive, the introduction of the telegraph, the supplanting of iron by steel, the marvelous inventions and growth of photographic art, the discovery of Neptune and the synthesis of madder, the putting of a girdle of electric wire about the earth, traversed by thought in the twinkling of an eye, and saw the introduction of the modern iron-clad, the torpedo, the submarine boat, and the self-propelling and dirigible air ship. He saw nations grow in deserts, state policies controlled by the work of the reaping machine, the issues of peace and war decided in the banking houses of New York, London, Paris, and Frankfort; Massachusetts and Minnesota, Maine and California, exchanging products to mutual advantage and profit; colonies organized by civilized races in India, South Africa, and throughout Australasia; continents and oceans traversed in days, the world circumscribed in weeks, months of work concentrated in a warship, or a transatlantic steamer, and a locomotive built in less time than he gave to his first little toy engine, two generations ago.

At sixty, this man of the century had read Darwin's Origin of Species, seen the invention of Bunsen and Kirchhoff making of the discoveries of Fraunhofer and the work of Huggins and Miller a bridge to the stars, and he learned through that dazzling light the composition of the sun and the nebulæ. He had seen the famous men-of-war of 1812, and taken pride in their achievements, but saw them cast into shade by the modern war vessel which his hands aided in building during our own civil war, and by the iron-clad "monitors" that the genius of Ericsson and Timby gave us in our time of peril. He saw slavery abolished by the arts and manufactures of the North, the gift to the nation of men of his own sort. Commerce was turned into new channels by the Suez Canal, the work of his colleague in engineering, De Lesseps; and the opening of the Pacific Railway, and the grand enterprise of Sibley and his lieutenants, the transcontinental telegraph, made the country of his birth safe against meridional dismemberment. Then he was ready to cry, "Now, Lord, let thy servant depart in peace!"

Could this man, born in the first year of the century, have lived to the last, what might he not have seen of further progress? We are ourselves asking: What remains for *us* to do? Where do we stand in this path without visible end? What has been accomplished in the promotion of the work of the man of science? What may we regard as practicable and possible in further advancement of research, and in the discovery of other of nature's unrevealed secrets? We are in the midst of the bustle of many partial developments. Where may we best seek our opportunities? We have seen the biologies reduced to formal science; the mathematics carried into space of the fourth dimension, and directed to the formulation of the motions of the sun, the moon, and the stars of the most distant universe; to the detection of new planets, the computation of the orbits and periodic times of the invisible elements of double stars. The law of evolution has been made to comprehend every department in which living force, whether vital or other, is carrying on the work of the Creator, including in its marvelous and continually extending field the development of protoplasm into man, nebulæ into solar and stellar systems, barbarism into civilization, families into nations, paganism into Christianity.

Chemistry has learned to analyze every compound, and is beginning to make syntheses of most complicated compositions, to guide us in reducing the metals from their ores, to produce dyes from basest wastes, to make an odorous or a tasteful extract in exact copy of those of nature, to give the world innumerable new and useful gifts. Physics offers us the electric light, and turns darkness and crime to day and peace, and, by this same singular energy, as the handmaid of steam, reaches out along our streets and drives, through its slender wire, hundreds of cars, with rapid pace, exerting the power of a thousand horses. Or it sends its thought-conveying vibrations along the line from New York to Chicago, from Boston to San Francisco, across the oceans; and the telephone speaks to us in the voice of our friend beyond the sunrise, or the telegraph brings us his thought from over seas, and the phonograph and the graphophone make it eternal. This most impressive of the sciences, most brilliant of the departments of natural phenomena, does more. It gives us measurement of the temperature of the moon, the heat of the sun, the extent and velocities of motion of those solar cyclones which cover a hundred thousand miles in a fraction of a second; it tells us the composition of all the heavenly bodies, the state of matter in distant sun and nebula, marks the direction and times the movements of the fixed or the falling star, gives us a clew to the laws governing the transformation of every form of energy into every other, and guides us in our search for the coming substitutes for the heat engines.

Geology teaches us the history of the worlds, the story of the days of creation, the method of development, and the construction of our own terrestrial home. It points out the hidden vein of precious metal, the location of the diamond, the site of ancient forests, now more precious than the carbon crystal, and of deposits of ores of iron, the most precious of all the metals, shows where to seek the subterranean streams that may irrigate and make blossom the most barren soils or the broadest deserts, the reservoirs from which to gather mineral oils for fuel and light, and to be converted into lovely dyes and to give comfort and life to thousands. It shows us how to secure, from the buried relics of a life in prehistoric seas, fruition of the gardens of the florist of the metropolis, the wheat fields of the West, the cotton fields of the South, and the acres of oats and rye in the East and the North, transferring the energies of the sunlight of the earliest days of creation to do the work of the world to-day. What is left to the man of science now? Needless to ask the question of him. A thousand new problems confront him and the old remain largely unsolved.

All life and movement, whether of man, animals, vegetation, seasons, suns and planets, arts, commerce, civilization, intellectual, moral or physical worlds, depend upon transformations of pre-existing energy. All studies, all work in the domain of the physical, the natural sciences, relate to transformations of energies and their mutual interactions and modifications. A century or two is small space in which to reduce all to weight and measure. We have learned to compute the velocity, to determine the methods of refraction and reflection of light; but we still know little of its exact character as motion of molecules. We know the related form, heat energy, in its sensible effects; but we are still unable to differentiate the one from the other. We can produce and utilize electricity in many ways, but we, as yet, do not even know what it is or how its transformations from other energies are effected. We work with these three forms of power, they are the amusement of the ignorant, the wonder of the sage, the slaves of humanity; but we do not even know what is the nature of the substance through which they act to produce their beautiful, their marvelous, their world-impelling effects. The ether is still to us an enigma, unsolved by the wisest, a riddle to the most expert investigator.

The chemist knows much of the composition of "compounds," but he has never seen, felt, or identified an "atom," and still vaguely dreams of a single first element into which all shall be resolved. He counts with unseeing eyes the number of atoms in a "molecule," but has never yet learned their form or grouping. Even with the aid of the physicist he loses track of their transformations in the furnace of the sun and the stars, and finds in the spectroscopic lines a strange language of which he lacks the key. He can isolate and weigh the phosphorus in a grammue of steel, but he cannot give us the phosphorescent fuel, the source of light of the firefly. He can reduce the muscle, fat, and nerve matter of the human system into their elements, but he cannot produce the storage batteries of brain and spine or the gymnotus' cells.

The astronomer weighs and measures the sun, the moon, the planets, and the nearer stars; but he stands aghast and amazed by that flying sphinx, "1830 Groombridge," the "run-away star," flying 200 miles a second, faster than it could fall from infinite space, and its origin, course, destiny are to him questions for the oracles. He has, as yet, no solution. He is lost amid the depths of space, he knows not where to look for a limit, or how to prove its non-existence. He asks with the believing and the unbelieving among the simple, How and when shall the "Heavens melt with fervent heat"? and, How long shall this wandering handful of worlds traverse the infinite safely and without that conflagrating collision with other systems or other worlds that, as seems possible now and then, at intervals of years or of centuries, causes a star to blaze out in the midst of darkness with a brilliancy incomparably greater than that of the sun? His little span of life is too short to permit him to follow the evolution of the worlds from their initial nebulæ, too brief to give him access to the secrets of their Maker.

The geologist tells us of the past history of all that lives, and of this spinning globe on which it has found foothold, falling into life from unknown space, and time, and depths, but he cannot tell us whence came all life, whence all spirits, all human and divine souls now constituting its living freight, as it wanders with unguessed mission through an unmeasured universe. He roughly traces its superficial changes from the days of mist, through the ages of creation and growth of all that has come into life; but he and the physicist and the astronomer are alike uncertain whether it shall endure a thousand million of years or a single day. The physicist predicts a limit of a few million years, the geologist believes many millions, but no man knows when life shall perish from the face of the earth.

The biologist can give microscopic measures and microphotographic pictures of the tissues, and can trace a nerve to its minutest ramifications; but we have yet to learn the secrets of the source of life, of method of production and application of energies, of those transformations that give form, structure, life, and power to the organism of monad or man. He exhibits the mechanism of the fish, but finds not the secret of separation of oxygen from the medium in which he lives, and cannot produce a submarine vessel. He knows the shape and movement of the bird, but flight remains to him a mystery. He measures the heat of the animal body, but biologist, chemist, physicist, and engineer, all together, give us no hint of the method of its production. They know, to an ounce, the power per cubic inch or per pound of the muscle, but neither one nor all can say how that power is originated, how transferred or how exerted by the transmitting threads of working muscle.

The engineer has, for a century, made steady progress in the adaptation of machinery to every purpose of modern life. He converts the potential energy of the vegetable life of a myriad earlier ages into steam power, and applies it to the impulsion of railway carriage, of steamship, and of mill; but, in the process, he wastes four-fifths or nine-tenths of it, and pays out principal where he might, perhaps, pay only interest. He turns the elastic force of expanding steam into an electric current, and sends it out to relieve the burden of the overworked horse; but he allows as much to slip from his grasp, often, as he usefully applies to his proposed work. He diverts the energy of combustion or of falling water into the new form, and the electric light, through his genius, gives illumination to street, and dwelling, and hall; but every light ray goes forth to its task carrying with it a sheaf of heat rays; and the glowworm shames the man, producing light without heat, and heat apart from light, and the researches of a Langley or a Hertz only exhibit our ignorance and comparative inefficiency. He measures the speed and power of the albatross, the eagle, and the swallow; but he only marvels the more at their beautiful movements and rapid flight. He captures the dolphin and overcomes the whale when they traverse the surface of the ocean, but he knows not how to follow them into the depths of the sea. He crowds his fellows into mills and factories, but sees no way of giving each an individual life and work, comfort and health in equal and fair quantity. The man of science, whatever his chosen task, whatever his field of labor, however high his attainments and whatever the magnitude of his accom-

plishments, finds acquisition of learning, gain in knowledge of the ways of nature, increasing appreciation of, and familiarity with, God's ways, only bring to his dazed eyes greater and more novel marvels, grander and wider sweep of opportunity, mightier and mightier mysteries, all challenging him to nobler aspirations, more earnest labor, higher aims. Every step toward higher, better, brighter life gives him reason for greater humility, larger faith, and stronger sense of the infinitude of duty and opportunity.

The work of the man of science is present still, and is never-ending. But, glancing at the past, he sees that he has no reason for discouragement; every reason for enthusiastic ambition. He sees a wonderful, a glorious, a fruitful work just begun, and his the privilege of taking part in it. His work is the basis of present highest human existence, the potential foundation of still nobler life. Great problems have been solved; greater and grander remain, which shall certainly be solved by him. His is the task of showing the way to make all the powers of nature genii aiding man; of giving comforts of every kind to his fellow, and powers of accomplishment of great work for public good; pointing out the way to give widely distributed enjoyment of life, leisure for moral development, for intellectual growth, opportunity for study of the universes, the attainment of highest physical, intellectual, moral ideals. He will yet penetrate the secrets of the living machine, learn how to evade the law of Carnot, to produce and apply the energies of chemical combination to the generation of heat without light, light without heat, power without waste; to transform thermal from chemical energy, without combustion at high temperature, as does the meanest animal; to convert it into mechanical power without the thermodynamic loss inherent in our heat engines, as does beast, bird, and worm; to obtain its full equivalent of electric energy, as does the nervous system of every living creature; to intelligently select and sort out the radiant energies into luminous, thermal, or other etheric forms, at his will, as does the unconscious bit of hardly living jelly floating in the spume of the wave crest of every tropical sea.

Chemist, physicist, naturalist, engineer—every member of our noble guild has his task and his opportunity. Could highest ambition and grandest aspiration ask more? The worker in pure science is finding his way to greater works, to higher ends in the promotion of the good of his fellows and the race; the man of applied science reduces to practice the principles thus revealed, and directly gives them their place and use. Many Lavoisiers and many Newtons are still to rise into fame; fields are opening for new Boyles, and later Foucaults and coming Faradays. Agassiz, Linnæus, Harvey, and Herschel have their legitimate successors; James Watt, Samuel Morse, George Stephenson, Robert Fulton, and our great contemporary discoverers and inventors are but the pioneers in a never-ending exploration of all the as yet unknown worlds of science. The coming men of genius are arising daily among the unobserved youthful disciples of these immortals. Their future and their fame should be no less glorious. What young man, entering these paths to-day, may not do so with ambition, hope, assurance of ample reward for such good work as he may do? What youth of honest spirit, persistent habit, steady aim, may not aspire to accomplish some one of these remaining tasks, and to become known to future generations, even though he may die, as often happens, unknown to contemporary fame? Who among us all can fritter away life, powers, opportunities, when such work lies open to all? What, in all the seen universe, can be offered of higher worth to the members of our latest of the fraternities?

And the way to the mountain peaks of science lies through the course which we have seen to be that invariably taken by the true lover of science. It comes of high aims, carefully laid plans, thorough preparation by preliminary investigation of the earlier progress of the pioneers, exact and full acquisition of existent related knowledge and equally accurate and persistent work in its advancement. The modern man of science is known by his works, and by this method of work. Where is worthier purpose sustained by worthier methods? His principles and those of nature are the same, and are eternal, for

> "Nature ever faithful is
> To such as trust her faithfulness,"

and science, of all pursuits of the intellect, best permits him to rise

> "And carry learning to its height
> Of untried powers and sane delight."

Natural science takes man nearest God; its field is the Maker's actual handiwork; it most nearly brings Creator and creature into actual touch;

> "Without halting, without rest,
> Lifting better up to best."

And we may well feel assured that,

> "Future or past, no richer secret folds,
> O friendless present! than thy bosom holds."

THE KNEE FEMININE.

THE difference of weight in the brains of men and women has long been a source of deep interest to all who discourse of equality and rights. Those extra ounces remain more or less a stumbling block to the unwary. Metaphysical justice refuses to regard them other than iniquitous. Yet certain structural differences escape such close scrutiny, notably that of the knee.

The structure of the knee feminine constitutes in itself a permanent disability for many masculine pursuits. The knee joint in women is a sexual characteristic, as Dr. Ely Van de Warker long ago pointed out. Viewed in front and extended, the joint in but slight degree intercepts the gradual taper into the leg. Viewed in a semiflexed position, the joint forms a smooth, ovate spheroid. The reason of this lies in the smallness of the patella in front and the narrowness of the articular surfaces of the tibia and femur, and which in man form the lateral prominences, and this is much more perfect as part of a sustaining column. Muscles designed to keep the body fixed upon the thighs in an erect position labor under the disadvantage of shortness of purchase, owing to the short distance—compared to that of man—between the crest of the ilium and the great trochanter. A man has a much longer purchase in the leverage existing between the trunk and extremities than a woman. The feminine foot, comparatively speaking, is less able to sustain weight than that of man, owing to its shortness and the more delicate structure of the tarsus and the metatarsus.

Women are not well constructed to stand many hours consecutively and every day. It is safe to affirm that they have instinctively avoided certain fields of skilled labor on purely anatomical grounds, in which the smaller quantity of brain substance proves less an adverse factor than the shallow pelvis, the peculiarity of the knee, and the delicate nature of the foot. These, as parts of a sustaining column, undeniably leave something to be desired. Even the right to vote would not confer on womankind the right to be soldiers. Equality, it appears, is quite as much an affair of the knee as of brains.—*Medical Record.*

WHAT CONSTITUTES A FILTH DISEASE.

Dr. S. W. ABBOTT, Boston, Mass.

THE doctrine that filth plays an important part in the causation of disease lies at the foundation of very much of the sanitary administration of cities and towns throughout all civilized countries. The popular impression, however—and undoubtedly the belief among a very large part of the medical profession, as well as among many of the officials who have charge of sanitary administration—is that filth in the ordinary sense of the word is itself the active cause of disease, and that little else is essential to the production of certain infectious diseases than to deposit a certain amount of filth, or to allow such filth to accumulate within the premises occupied by a given population, in order to generate a pestilence. Hence the activity of sanitary bureaus in sweeping out filth, in cleansing foul spots, in removing garbage, in depositing tons of disinfectants in cesspools, catch basins, and sewers. This activity in the cleansing of towns, the removal of filth, the sanitation of houses, cellars, and yards, is commendable so long as the true *role* of filth in the causation of disease is not lost sight of, and the entire energy of sanitary organizations is not expended in this one direction.

Undoubtedly each and all of the so-called filth diseases may find victims in houses that are absolutely faultless, provided that conditions otherwise favorable exist in such houses, the prime condition being the presence of human beings. A child sick with diphtheria in any house whatever constitutes a menace to every one who lives in the house, and especially to the younger portion of the household. This again is but one of the essential conditions to the propagation of infectious disease.

The results of the experimental researches of recent years, in regard to the natural history of infectious diseases, appear to show that what the older observers were wont to call causes were conditions only, and that overcrowding or density of population, faulty ventilation, and the presence of filth are simply the favorable and unfavorable conditions in the propagation of disease, and not in any sense its cause.

Analogy would teach us that the actual cause of an infectious disease is the disease itself—that is to say, a previous case—and the more we learn of the origin of the epidemics, as well as of so-called sporadic cases, the more we are inclined to look for previous cases as the true cause of origin. Nor does the fact that we do not find the previous case prove its non-existence.

By some authorities small-pox is called a filth disease, and experience has shown that the liability to its occurrence is increased by the presence of filth. About one-half of the local outbreaks in Massachusetts in the last ten years have occurred in paper mill towns and in the families of persons engaged in sorting rags, and in nearly every instance it was found that the rags had been collected in some large town in which small-pox had recently prevailed. In this case the presumption is very strong that the filth or the dust of the rags was simply the medium of contagion, the bales having probably contained rags which had had direct connection with the persons suffering with small-pox.

In the same category may be placed *anthrax*, a disease rare in the United States, but occasionally introduced into factories engaged in the sorting and preparation of foreign horse hair. The presence of the *materies morbi* in the dust of these factories is not to be wondered at, when it is known that such hair is sometimes shorn from animals which have died of anthrax.

Another disease which recent inquiries show conclusively to be propagated through the medium of dust-laden atmosphere is that most destructive of all diseases, *phthisis*. The danger which exists in the distribution of the dried sputa of phthisical subjects cannot be overestimated.

The liability of infection by *scarlet fever* is undoubtedly increased by the presence of dust; since the contagious principle of this disease, so far as can be learned, exists largely in the particles of dried epithelial scales which, falling from the body, mingle with dust of apartments, and thus spread the infection from the sick to the well.

In the same category may be placed *typhoid fever*. In fact, this disease may fairly be styled the chief of filth diseases, and although it may not be possible to trace the typhoid bacillus *en route* from the ileum of the sick to the œsophagus of the well by the medium of any drink in which milk or water is used, the evidence as to its transmission in this manner is conclusive. Lieberman says of the disease: "Daily observation is sufficient to show that the decomposition of organic substances, and of excrementitious substances, is not of itself sufficient to produce typhoid fever. There are multitudes of houses in which the effluvia of the privies can be smelled through all the rooms, and in which the inhabitants are constantly inhaling sewer gas; and neither the temporary nor permanent residents are attacked with typhoid fever." We are, therefore, forced to the conclusion that the poison of typhoid fever does not originate in filth or decomposing substances, but simply finds in them favorable conditions for its spread.

The evidence that both *cholera* and *yellow fever* are propagated by sewage—polluted water supply—is very strong. In both cases the introduction of the disease from without appears to be essential to its propagation. Filth is simply a medium favorable to its spread.

The relation of *diphtheria* to filth is not so clear as in some of the infectious diseases, and it is often claimed that sewer gas is the common cause of the disease. That such filth may be a proper soil for the cultivation of the disease, when once introduced, I have no doubt, but the claim that the disease originates in it is open to question.

The point which I desire to emphasize is not that the removal of filth should be discouraged, but that when it is done it should be done intelligently, and with this principle in view: that filth is a condition rather than a cause; that it is the soil for the culture and transmission of the infection, and not the infection itself.—*Tennessee State Board of Health Bulletin.*

SOME RECENT ADVANCES IN SOLAR SPECTROSCOPY.

By Prof. C. A. YOUNG.

WITHIN the last three or four years our knowledge of the solar spectrum and of the phenomena which are studied by means of the spectroscopic observation of the sun has made substantial progress. In the present article we propose to enumerate the principal advances, and to call attention to such as are specially interesting or important.

Our limits permit only a passing reference to the recent work of the veteran Janssen, who, though no longer physically fit for mountain climbing, had himself carried to the summit of Mt. Blanc by a force of porters in order to study the debated question whether the great oxygen lines in the red region of the solar spectrum might not be, partly at least, of solar origin, notwithstanding the undoubted fact that they are mainly telluric. His observations on the mountain, taken in connection with those he made upon the electric light on the Eiffel tower as seen from Meudon, have settled the question in the negative.

We must content ourselves also with little more than a mere mention of the great map of the solar spectrum published last year by the Nice observatory; the work of Thollen, who however did not live to see it finished. It extends from the red to the green, and is on a larger scale and more full of detail than any other yet issued; it is specially valuable for the manner in which it brings out the distinction between the telluric lines, originating in the atmosphere of the earth, and those which are truly solar, but on the other hand its scale is purely arbitrary, and this greatly limits its utility. On the whole the new edition of Rowland's photographic map, which now covers the whole of the spectrum except a small region at the extreme red end, is comparably more satisfactory; it represents the ordinary appearance of the spectrum with the minutest accuracy, and bears an absolutely trustworthy scale of wave lengths. Its only drawback is that when the sun is near the horizon it ceases to correspond to the appearance presented: the telluric lines become so numerous and intense as to transform entirely the whole aspect of certain regions of the spectrum, and the observer then is driven to Thollen's map as the only one of much use under the circumstances. A new map of the spectrum, also photographic, is announced for early issue by Mr. Higgs, of Liverpool, who has already produced plates exceeding in beauty and clearness of definition even the best of Rowland's; but his work has been done with a Rowland grating, so that our American physicist can still claim a generous share of the credit for its excellence. In fact, the same may be said with reference to every piece of spectroscopic work we shall have occasion to speak of.

Duner, in Sweden, has recently repeated the investigation of the sun's rotation as measured by the displacement of the lines of the spectrum at the eastern and western edges of the sun's disk. His results confirm those of previous observers, extend them to higher latitudes, and are far more precise. Incidentally he confirms an old observation of the writer's in regard to the structure of sun spot spectra, finding them to be made up of fine, closely packed, dark lines, and not produced by a mere continuous absorption. This fact is of importance in its bearings upon the theory of the spots, but for some reason has remained without verification until now.

The most important piece of recent work in the line of solar spectroscopy is unquestionably Rowland's comparison of the solar spectrum with the spectra of the various chemical elements. It is, of course, to some extent only a repetition of work already done by others, but the new investigation is so much more thorough, and made with instruments of so much greater power, that its results are incomparably more trustworthy. The work is not yet entirely finished, but it has already greatly extended our knowledge, both by increasing the number of the elements recognized as present in the sun and also in increasing the number of the lines identified as belonging to the spectra of the elements previously known. A large majority of the lines of the solar spectrum are now thus identified, and no less than thirty-six of the terrestrial elements are recognized with certainty in the sun, while eight remain doubtful, and fifteen fail to give any evidence of their presence after the most careful search; ten remained to be tried at the time when the preliminary results were published last spring. Of the sixteen elements added by this investigation to our former list, the most important are carbon, silicon, silver and zinc: the detection in the sun of the newly discovered and rare metal germanium is also interesting; gallium as yet remains in the list of the untried. The most conspicuous of the "absentees" are nitrogen, sulphur, phosphorus, mercury, antimony and bismuth, while among those not yet examined are oxygen, bromine, chlorine, iodine and fluorine.

Hardly less interesting is the recent work of Hale, of Chicago, and Deslandres, of Paris, upon the ultra-violet spectrum of the chromosphere and prominences as studied by means of photography. It has long been known that the two wide, dark bands known as H and K at the violet end of the solar spectrum are "reversed" in the spectrum of the chromosphere and in the neighborhood of sun spots in the same manner as the hydrogen lines; indeed, this fact, in connection with some other circumstances, led some to suppose that these

bands are really due to hydrogen, and not to calcium, as generally admitted. It now turns out that their observation by photography is as easy as their visual observation is difficult, and that in the spectrum of the chromosphere and prominences they appear as bright lines exceedingly thin and well defined; in striking contrast with their width and haziness as dark lines in the spectrum of the photosphere. Moreover, H is accompanied by a companion line just below it, and well within the dark shade. This line, which has been often observed visually, proves to be invariably present in the photographs; and the same is true of another line above K (just at the extreme limit of vision) which had also been occasionally observed before. The photographs also bring out a number of other lines (four at least), quite beyond the limit of visibility; and these six lines have all been unmistakably identified as belonging to the remarkable series of ultra-violet hydrogen lines which are so impressively conspicuous as wide black bands in the spectra of the great white stars like Sirius and Vega, but are missing in the spectra of the sun and of the stars that resemble it, that is as dark lines. Probably they are really present, but are comparatively faint, and masked by the heavy lines of other metals that crowd that part of the solar spectrum; at least this is the opinion of Rowland. But their detection as bright lines is very interesting as removing a puzzling anomaly.

The close coincidence of H with its hydrogen neighbor also explains another fact which has caused a great deal of perplexity; namely, that in the "Sirian" stars H is tremendously black and strong, and K, when visible at all, is very faint and thin; while on the other hand, in the spectrum of the sun and of the stars that resemble the sun (*Alpha* Aurigæ, for instance), H and K are about alike, and in some cases K is even the stronger of the two. The matter is now clear; in the spectrum of Sirius and its congeners the band at H is due to hydrogen, while in the spectrum of Capella it is mainly due, not to hydrogen, but to the same substance that produces the H and K of the solar spectrum.

These bands, as has been said, are generally attributed to *calcium*, and this view may be correct; but a number of facts make one hesitate at accepting the identification as final. It is true that the spectrum of the metal in the electric arc presents two lines that coincide perfectly with the center of the two bands; but the other lines of calcium, which in our laboratory experiments are more conspicuous than these, seldom present themselves in the spectrum of the prominences, and when they do, only faintly, while H and K incomparably outshine the lines of hydrogen itself, and attain higher elevations. Moreover, in the photographs of the spectrum of the corona obtained during the eclipse of 1882, these lines dominate everything. The facts seem to indicate a gas lighter than hydrogen itself, and almost compel the belief that if they are really due to calcium vapor it must be calcium in a very different condition from any with which we are acquainted in our laboratories. But it is perhaps quite conceivable that under solar conditions the metal may assume an allotropic state in which its vapor density becomes very low.

Mr. Hale has taken a further step in utilizing these two lines to enable him to photograph the prominences themselves, and with very fair success. The idea is not new. Some twenty years ago the writer succeeded in getting a photographic impression of a prominence by using a spectroscope with a widely opened slit, and working through the hydrogen line near G in the blue part of the spectrum. The trial made it obvious, however, that no practical result could be reached by the photographic processes then in vogue. But these bright H and K lines of the chromosphere spectrum, falling as they do each in the center of a wide, dark space in the solar spectrum, are photographed with the greatest ease; and by opening the slit of the spectroscope it is possible, if the clock work of the telescope runs accurately, to secure a really good picture of the form and structure of quite a large prominence. By fitting the instrument with a mechanism devised by Mr. Hale, such that the slit can be carried across the prominence while the sensitive plate is protected by a moving diaphragm, except where the image of the slit falls at the moment, it is possible to cover a much wider area with the picture. In fact, by an arrangement devised by Deslandres, one could photograph in a single operation the chromosphere and prominences around the whole circumference of the sun.

College of New Jersey, Princeton, Nov. 16, 1891.

—*Popular Science News.*

[COUNTRY GENTLEMAN.]

A HOME MADE INCUBATOR.

IN attempting to comply with the request for my experience with incubators, it is well perhaps to premise by saying that previous to three years ago I hardly knew the difference between a Leghorn and a Plymouth Rock fowl; hence, I had everything to learn.

Profiting by the cautions and experiences noted in our reading as well as heard in conversations with poultry raisers, we did not go into the business on any large scale; so have no tales to relate of large flocks or extraordinary results, our intentions being to gradually work up to something larger. Again, so far in our work the outcome has been nothing astonishing; eggs have not all hatched, chicks have died; on the whole, however, we believe we have been fairly successful, and that we have no reason to feel discouraged. Others ought to do just as well.

The plans for the incubator here illustrated were found a number of years ago in some paper; by whom contributed is not known. After much study of the plans, and discussion of the subject in all its details, it seemed feasible, so we attempted to make a small one, holding only five dozen eggs, the first trial of which resulted in our securing only one rooster out of the sixty eggs. Over forty of the eggs had nearly full grown dead chicks in them, and we concluded—because the live one only came out on the twenty-third day—that there had not been enough heat.

Concluding the fault lay with the small water tank, which allowed the water to become either too cold or too hot, we set about constructing an incubator to hold between 500 and 600 eggs. As it was entirely home made, excepting the water tank, I send these sketches and quite a full explanation, which I hope will enable your correspondent and others to make one that can be operated successfully the first time, the proper care being given. It will be found best to build this hatcher on the spot where it is to stand, as it is too heavy to move from one place to another. The room in which it is kept should have a temperature of between 60° and 70,° and it can conveniently be used as a brooder room until the weather is warm enough to take the chicks out of doors.

Fig. 1 shows an external view of the complete machine, as it appears when full of eggs. Its outside

FIG. 1.

length is 10 feet, width 3½ feet, height 2½ feet, making a large sized box. Inside of this is another box, four inches smaller each way than the outside one; then comes the tank, which is 9 feet long, 8 inches high, and 2¼ feet wide. Below the tank are the drawers, six in number, each 17 inches wide and 4 inches high, and immediately beneath these come the ventilating chambers, six inches deep, and of the same width and length as the drawers.

The cross section at Fig. 2 shows more plainly the details of construction, and to this reference is made in

FIG. 2.—W, water tank; D, drawers; V, ventilator; S, sawdust.

the following directions: The first thing to build is the bottom of the large outer box, which is done by laying matched flooring (second quality) on 3½ feet long pieces of 2×4 scantling, using five pieces, one five inches from each end and three in between, setting them on edge. After the boards are fastened to these, the whole thing is turned the other side up, so that the scantlings are on top. Scantlings are cut into 22 inch lengths and used for the back, being placed in the same relative position as those on the bottom, and set on the edges of the latter, the back boards being firmly nailed on them.

The ends are also built up several boards high in the same way, a 22 inch being used flatwise at the back and front for each corner. The bottom is now filled with fine sawdust packed tightly, up level with the top of the scantling. Then the floor of the inner box is laid down, leaving a four inch space between the front and rear sides and being just long enough to come to the outer edge of the end scantling. In forming the front, it is first boarded up for a foot from the floor, but the sawdust is not packed against it; the ends and back of the inner box are built up and the space at once filled with sawdust, more especially at the back, which can be entirely filled up to the top of the scantlings.

The most difficult part of building this incubator is found in fitting the drawers, which must fit as tightly as possible, yet work easily and smoothly, else the eggs will be too roughly shaken. On edges of the boards of the sides of the two boxes, a very smooth board six inches wide is laid, so that its highest side, on which the drawers slide, is just six inches above the inside of the bottom of the inner box. This forms an air chamber nine feet long and two and a half feet wide, which is divided into six equal compartments by one inch pieces as long as the chamber is wide and 5½ inches high; on the upper edge is fastened a half inch strip of the same length, one and a half inches wide, which being laid flatwise makes the height of the partitions equal to that of the front when fixed as just directed, and these thus form good sliding tracks for the drawers; at the two ends a narrow strip is fastened on the inside at the same height for the sides of the two end drawers.

In making the drawers, half inch stuff is used for the sides, and inch stuff for the ends. The drawers are 17½ inches wide outside and 3 feet long outside. Fig. 4 gives a good idea of their construction, as the 6

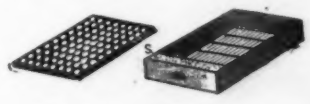


FIG. 3. FIG. 4.

inches in front, which corresponds to the sawdust between the two boxes, is also filled with the same material, and covered tightly with smooth, light boards on both top and bottom, an inch board being used as a partition, as shown in the illustration.

In forming the bottom, four strips one-fourth inch thick and an inch wide are nailed across inside of the sides, a quarter of an inch above the lower edge. Over these strips was first laid and stretched a piece of cheese cloth, or cheap factory, being kept in place with small tacks. On this was then laid a tray made of tin, and having seven dozen oblong holes cut in, the centers being 2 inches apart crosswise and 2½ inches lengthwise, in which the eggs are laid (Fig. 3).

Between the drawers, on the pieces on which they slide, is placed a 4½ inch wide strip of one-half inch stuff as long as the drawers; inside of the inner box these strips are a half inch higher than the drawers, but the six inches at the front ends are made to be only an eighth of an inch higher than the drawers, and support a six inch board laid flat, similar to the one below the drawers, and on this board rest the remainder of the boards forming the fronts of the two boxes, until they are equal in height to the rear. Two pieces of band iron, not very heavy and long enough to reach from end to end, are then laid on the partitions above the drawers, being also supported at the ends, and on this is laid the tank, which thus lies a half inch above the upper edge of the drawers and allows them to work freely.

In finishing the fronts, provision must be made for the faucet or stop-cock and tube for drawing water from the tank, which comes out at the side as shown, an inch hole being required. All that remains to be done is to put the top on the inner box, and fill the ends, sides and tops completely with sawdust; then covering the outer box, allowing for the 1½ inch tube for filling the tank, which comes up at the top. We prefer to put the boards on crosswise, instead of lengthwise, for the top of the outer box, as it tends to hold the sides firmer. With an inch auger bore one hole into each of the ventilating chambers beneath the drawers, going through both boards; then a piece of tin is bent so as to form a tube six inches long and placed in the hole, reaching from the air chamber to the outside; this properly being done before any sawdust is placed in the front wall, it being then packed around the tube.

The water used in our incubator was taken from the stop-cock shown at left hand end of Fig. 1, and was heated in a boiler standing on a stove which we used to keep the incubator room warm; the stove cost $6.50, and was an excellent heater. The water was returned by using a watering pot and pouring it into the tank, first placing a large funnel in the pipe shown on top at the right hand of Fig. 1, which was always kept covered with a metal cap, except just while the water was being put in. For the first week it was usually necessary to reheat about eight or ten gallons of water twice a day, getting it up to about 200°, not quite boiling; for the rest of the time, from four to six gallons would be sufficient, but the exact amount can only be found by experimenting.

The incubator now being ready for the eggs, my mode of procedure was to fill the tank with hot water, lay a thermometer in a drawer, and for a week experiment as to the proper quantity of water to draw off each day to reheat and pour back into the tank. After this length of time we were able to keep the temperature quite uniformly at 103,° which is the proper heat; of course there was some variation, occasionally getting down to 98° or up to 106,° but only for a short time, as more hot water would remedy the coolness and more air the excess of heat.

As to thermometers, it is of course the best way to buy a good one for a good price, but I have been satisfied with the cheap ones for 20 or 25 cents, to be found in any hardware store. I, however, was very careful and tested my thermometer by means of a doctor's fever thermometer, (which is necessarily very accurate); mine happened to be just right, and was marked correctly. Even if it had been some degrees out of the way, by knowing just how much, one could easily make allowance. But don't try to do anything without a good tested thermometer, and it is better to have two, as one may accidentally be broken just at a most critical time and cannot be replaced without more or less delay.

The regulation of the temperature being understood, I fill as many drawers as I have eggs for, be it one or four. I always kept at least two drawers empty, as I found that I could have no better place for the chicks just as they came out of the shell than these drawers, which would accommodate them nicely for two days, or even three at a pinch.

For the first three days after the eggs were in they were close and dry, but after that each egg was turned completely over, morning and night, and sprinkled with water of a temperature of about 110°; in addition, a sponge as large as an egg was kept in each drawer having eggs, and was wet twice a day with hot water. A thermometer also was kept on top of the eggs. At the end of the first week I examined the eggs through an egg tester (Fig. 5), which

FIG. 5.

FIG. 6.

is of heavy cardboard, folded and kept in place by having cloth pasted around it. It is 4 inches long, 2 inches wide and 1½ inches high; one end being entirely open, the other having an oval shaped opening. By placing an egg against this hole, holding it toward a strong lamp light and looking at it through the open end, one can readily tell whether or not the egg is fertile and likely to bring forth a chick. If good, it will present an appearance similar to that roughly shown in Fig. 6; toward the upper side of the egg will be seen a dark spot about as large as a pea, and from it branch numerous blood and other vessels in every direction. By turning the egg partly around, this spot and its branches will be seen to move, always with a tendency toward the higher side.

As a rule, two-thirds of the eggs at least should be fertile, though the season of the year has a great influence on this point. The infertile eggs at this time can be removed and kept in a cool place until the chicks come out, when, after being boiled hard, they will be the best food that can be given them for the first two or three days, and it will save good eggs. Another advantage is, that the other eggs can be put together in less space and fresh eggs put in; so that chicks can be had coming every week.

During the last week of incubation, care must be used not to have too much hot water, as the temperature of the drawer will be greatly increased by the heat of the chicks; hence, if as much or as hot water were used as is required the first week, it would be altogether too warm, and the chicks would likely die in the shell when nearly grown. As the hatching begins, it is well to keep watch and remove them to another drawer, as in their efforts to move they might injure themselves, and the hatching drawer also is usually too wet for their well doing. In the dry drawer they soon dry off and become lively, and after

twenty-four hours are ready for their first meal of hard boiled eggs, which for the first two days is given at very short intervals, being careful to see that each one gets food, otherwise the weaker ones may suffer.

It is necessary that the room in which the incubator is should for best results be kept quite warm, day and night, especially where the incubator is run in severe weather; otherwise it will be a difficult matter to maintain an equable temperature in the egg drawers.

With our incubator we have been able to hatch from 90 to 95 per cent. of the fertile eggs. The chicks have always been strong, except a few that were crippled in their legs, these being immediately killed, after having experimented for some time on several in a fruitless endeavor to cure them; the peculiarity lying in having no command of their legs at all, thus being unable to stand. SUSIE P. SUMMEY.

Niagara County, N. Y.

ESTIVATION.

IN a series of articles published in this journal, I have studied the action exerted by cold upon different animals, which, during the winter season, retire to various places of shelter, become torpid and live upon their reserves while awaiting the return of a less severe temperature. This is what is called hibernation. Estivation, a pretty badly selected name, as we shall see further along, is exactly the opposite phenomenon. It is, moreover, much rarer than the first, and among the vertebrates scarcely presents itself except among a few of the terrestrial inhabitants of tropical regions. In these regions, cold is not to be feared. The only period during which the alimentation of animals is rendered difficult is the dry season. In fact, almost all of the watercourses are then dried up, and the flora disappears for the most part. So, during this period, some animals bury themselves in the earth, and become torpid, precisely as do the marmots and squirrels during the winter of our regions. This is what is called estivation. This phenomenon, which is quite rare, is especially well marked in a mammal of the group of insectivora, the tanrec, and among the lower vertebrates of the group of dipnoids. This word "estivation," which is directly opposed to hibernation, seems to us to be quite inappropriate, for, in reality, it is not the elevation of temperature that is the cause of it, but rather the concomitant dryness. That is so true that, in our temperate regions, the phenomena of estivation are well marked among the fresh water invertebrates that inhabit the ponds or brooks that are dried up in summer.

The tanrec (*Centetes setosus*) is an insectivore closely allied to the hedgehogs, and peculiar to the island of Madagascar. It is distinguished from the hedgehogs especially by the small number of quills, which are shorter and softer, and intermixed with many silky hairs. None of the known species is capable of rolling itself up into a ball. The tanrec lives, as a general thing, near the edge of the water, which it seems to be very fond of, or upon the seashore or in the vicinity of rivers and marshes.

During the rainy season, toward the month of December, it leads a life of activity. It remains concealed during the day, but at night it starts out in search of its prey, and greedily devours insects, worms, snails and lizards. It is during this season, from December to June, that it accumulates the reserve materials, fat especially, that will be necessary for it during its period of estivation. When the dryness is about to begin, the tanrec digs a shallow burrow and sleeps therein for nearly six months, from June to November. This estival sleep is absolutely comparable, from a physiological standpoint, to the hibernal sleep of the marmot. There is scarcely any animal but the tanrec, among the mammals, that exhibits so great a sensitiveness to dryness and heat. As a general thing, it is true the animals of the tropical regions,

FIG. 1.—THE TANREC OF MADAGASCAR.

lions especially, scarcely ever make their appearance during the day, but prefer to await twilight or night: yet there are others, such as the jerboa, of Egypt (*Haltomys Ægyptiacus*), that appear in nowise to dread the rays of the African sun, and show themselves at noonday, while the sun is, so to speak, at a white heat.

The group of dipnoids, intermediate between the batrachians and fishes, comprises at present but three animals, the *Lepidosiren paradoxa*, in the affluents of the Amazon; the *Protopterus annectens*, of Gambia and Senegal (White Nile and Niger); and the *Ceratodus Forsteri*, of Australia (the Mary and Burnett Rivers of Queensland). As well known, these animals, whose anatomical structure greatly resembles that of the fishes, possess a well developed bronchial apparatus that allows them to breathe in water, and a pulmonary apparatus (transformation of the swimming bladder) which renders them capable of absorbing the oxygen of the air. This conformation, analogous to that of the axolotl, is connected with their conditions of existence. During the rainy season they live after the manner of fishes, and breathe in the water by means of their bronchial apparatus. During the dry season, when the marshes are dried up, they enter the mud to various depths, invested with a sort

FIG. 2.—THE JERBOA OF EGYPT.

of tough, mucous cocoon. The pulmonary apparatus then enters into play.

The *Protopterus annectens* has been studied with some care during its period of estivation, and the observations that have been made upon it we shall now recapitulate.

During the entire dry season, which lasts about nine months, the Protopterus remains buried in the dried-up mud, at a depth of about 5 ft., and is surrounded by a sort of cocoon, which incloses it hermetically. The clod of earth in which it is situated is traversed by a channel with smooth sides lined with a hardened mucilaginous substance. This channel terminates at a part of the cocoon that is thinner than the rest and easily permeable, and that corresponds to the animal's head. Although respiration must be greatly retarded during this period, it will be seen that this arrangement assures the renewal of the air in the interior of the cocoon.

When the fragments of the hardened case are removed, there is laid bare the mucous cocoon, of ovoid form and chestnut brown color, in the interior of which the Protopterus is bent double, as shown in Fig. 4. Upon afterward detaching the cocoon, we bring the animal to view. The entire surface of its body is found to be covered with a very thin coat of varnish formed of coagulated mucus. The cocoon is very probably designed to protect the animal against the mechanical action of the mud, which contracts in drying, and the varnish to prevent desiccation.

The animal is bent double. The tail, which is very broad and of a very intense red, covers the whole anterior portion of the body with the exception of the nostrils and mouth. The appendages are applied against the trunk and are more or less protected by the wide tail, which forms a sort of membranous veil fastened by the coat of varnish to the head and trunk of the animal.

The Protopterus in a state of lethargy presents a certain number of interesting peculiarities. During this period it has two respiratory apparatus, viz., first, the swimming bladder transformed into a lung, and second, the wide membranous tail traversed by an extremely close network of capillary blood vessels. The air that enters through the channel and the thin side of the cocoon is, in the interior of the latter, absorbed by the lung and partly by the caudal veil, rich in capillary blood vessels.

According to Parker, the lateral muscles of the tail become atrophied to such a point that the muscular fibers are reduced to the perimysium. The contractile substance degenerates and is absorbed by the amiboeytes of the animal (white globules playing the role of phagocytes), probably in the way of nutritive materials.

From these data it is easy to imagine the succession

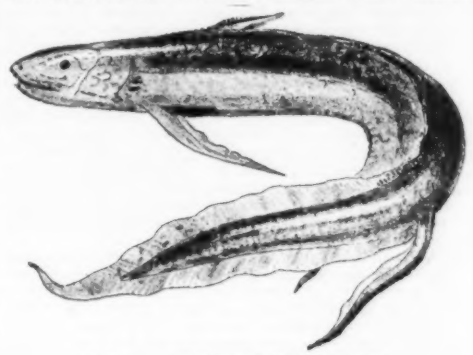


FIG. 3.—THE PROTOPTERUS.

of the phenomena that must occur at the period of the drying up of the water courses inhabited by the Protopterus. It buries itself in the mud and lines the side of the channel that it forms therein with a coat of mucus, which prevents the channel from closing up later on. It lies in the mud and covers its retreat with a layer of mucus, which constitutes the cocoon. Finally it bends double, and a thin coat of this same mucus glues, after the manner of a varnish, the tail of the animal to the anterior portion of the body. It is at this moment that the tail and the lung begin to operate like organs of aerial respiration. When the rainy season returns the marshes become refilled with water, and the Protopterus then rapidly resumes its active life. The mud softens, the cocoon and the varnish dissolve in the water in the course of about an hour, the tail loosens itself from the trunk, and the Protopterus then begins to swim. Shortly afterward, in the month of August, it couples and lays eggs in strings at the bottom of the water, like the majority of the amphibians.

FIG. 4.—THE PROTOPTERUS IN ITS COCOON.

B, mouth; M A, extremity of anterior appendages; M P, posterior appendage; E C, extremity of the tail; N C, tail; V, veil fastened to the head and trunk.

It will be seen that the Protopterus and the other dipnoids, in order to assure of the preservation of the species, are compelled to pass into an estival sleep for three-quarters of their life (nine months out of twelve), leading a free and active life scarcely for a quarter. It is very probable that to this biological peculiarity is due the extraordinary persistence of these species, which are not well prepared for the contest for existence. In fact, there have been found in the Devonian and Trias of America the teeth of *Ceratodus* which are absolutely identical with those of the present *Ceratodus*. These dipnoids seem to have been preserved from these geological epochs up to our time. This is an example analogous to that furnished by the lingula, the Cambrian species of which are hardly distinguishable from recent forms.—*L. Cuenot, in Le Naturaliste.*

ANTIQUARIAN DISCOVERIES NEAR ALEXANDRIA.

THE Cairo correspondent of the London *Times* writes as follows: In the *Times* of October 12 appeared a brief telegraphic announcement of the late interesting antiquarian discoveries at Abukir, distant 13½ miles by rail eastward from Alexandria. Excavations are being continued under the direction of Daninos Pasha, a *savant* well qualified for the work, to whom is due the merit of the discoveries; and, if government will supply the funds necessary to enable him to continue his researches, there are abundant indications that valuable "finds" will be made in a locality hitherto almost neglected by archæologists, and presenting much that is interesting, especially to students of the Græco-Roman period.

At four to six feet below the surface the diggers found three statues in rose granite, ten feet high, lying faces downward, among the ruins of a temple, of which part of the outer wall with lower portions of columns and several square yards of flooring have been laid bare. The statues had been originally erected at or within the temple, and one of them is lying in front of its pedestal, which is about three feet high. They represent in a group, according to the hieroglyphic inscription, Rameses II. (the Greek Sesostris) and his Queen Hentmara seated. The third statue is of Rameses II. in an upright posture, wearing a pleated tunic, bracelets, military crown, and a girdle bearing the inscription, "Beloved of Seth." At his left side he holds a scepter, surmounted by the head of his son

Menephtah (the Pharaoh of the Exodus), whose cartouch is inscribed on the scepter. On the plinth at his back, which is of equal height with the statue, is chiseled a bass-relief of Queen Hentmara in profile, wearing a pleated tunic and the royal tress. The inscription above her head is "Daughter of the king—beloved of her father—royal spouse—great favorite Hentmara." On the back of the plinth is carved the royal banner of Rameses II., with all his known titles and appellations. The execution of the three statues is in the plain, vigorous style of the Twelfth Dynasty. The feet of Rameses, which had been broken off in one piece with a clean fracture, were found at a few yards distance. The two heads of the group have also been broken off, and are being searched for.

It is surmised that the temple and statues were overthrown after the edict of Theodosius, A. D. 380, abolishing the Egyptian religion, but nothing has yet been discovered to identify the temple with any of those known to have existed during the Egyptian or Græco-Roman periods. Dr. Neroutsos Bey's interpretation of the inscription is—Hentmara, daughter of the king, beloved of her father (*i. e.* the preceding king, Osiris Menephtah, who was father of both Rameses and Hentmara), royal spouse (of Rameses II.), the (referring also to Rameses) great favorite of Seth.

The Pharaohs, following the example of Osiris, King of the Gods, and his sister Isis, had the prerogative of espousing their own sisters, and this custom, consecrated by both the civil and religious law, was followed in several instances by the Ptolemies.

Dr. Neroutsos, who is a well known Egyptologist, has lately published a work entitled "L'Ancienne Alexandrie," embodying his researches, made during a long residence, and he is perhaps the greatest living authority upon the topography of the ancient city and neighborhood of Alexandria. Referring to the locality in which the above mentioned antiquities were found, and which abounds with remains of old buildings, he recommends that explorers should seek to identify—

1. The small Egyptian town Menouth, with its temple to Isis, and subterranean burial places. Such a place has just been discovered by Daninos Pasha, in the solid rock, entered by a vertical shaft 40 feet deep, and a sloping staircase of 45 steps, terminating at the bottom of the shaft, where a series of galleries commence, extending in length to 170 feet.

2. The Græco-Roman village Zephyrion, where stood a temple to Artemis Sotera and numerous country villas.

3. The headland Zephyrion, on the highest point of which was a temple to Venus Arsinoe, Protectress of Mariners.

4. The Byzantine monastery of St. Cyr, corrupted to Abba Kyr, whence the name of the present town of Abukir.

The monastery and neighboring buildings were destroyed by an earthquake, followed by a tidal wave, soon after the capture of Alexandria by the Arabs. More than a dozen sphinxes and ruins of massive buildings, submerged by that catastrophe, and subsequently, are now plainly visible in the shallow waters of the bay.

DUST.

By J. G. McPHERSON.

SOME of the most enchanting phenomena in nature are dependent for their very existence upon singularly unimportant things; and some phenomena that in one form or another daily attract our attention are produced by startlingly overlooked material. What is the agent that magically transforms the leaden heavens into the gorgeous afterglow of autumn, when the varied and evanescent colors chase each other in fantastic brilliancy? What is the source of the beautiful, brilliant, and varied coloring of the waters of the Mediterranean, or of the most extraordinary brilliant blue of the crystal waters of the tarns in the Cordilleras? What produces the awe-inspiring deep blue of the zenith in a clear summer evening, when the eye tries to reach the absolute? Whence come the gentle, refreshing rain, the biting sleet, the stupefying fog, the chilling mist, the virgin snow, the glimmering haze, or the pelting hail? What raises water to the state of ebullition in the process of heat application for boiling? What is the source of much of the wound putrefaction and the generation and spread of sickness and disease? What, in fact, is one of the most marvelous agents in producing beauty for the eye's gratification, refreshment to the arid soil, sickness and death to the frame of man and beast? That agent is *dust*.

And yet no significance is given to dust unless it appears in large and troublesome quantities. It requires the persistent annoyance of dust clouds to excite any attention. Dust, however, demands to be noticed, even when not in that collected, irritating motion known in Scotland as *stour*. The dust particles floating in the atmosphere or suspended in the water have a most important influence upon the imagination, as well as upon the comfort of man. Though so small that a microscope magnifying 1,600 diameters is required to discern them, they at times sorely tax the patience of the tidy housekeeper and the skill of the anxious surgeon. An æsthetic eye is charmed with their gorgeous transformation effects; yet some are more real emissaries of evil than poet or painter ever conceived.

Until the famous discovery made by Mr. John Aitken, of Falkirk, a few years ago, no one could reasonably account for the existence of rain. It was said by physicists that cloud particles were attracted by the law of gravitation under certain conditions of temperature and pressure. But this famous experimentalist and observer found out that without dust there could be no rain; there would be nothing but continuous dew. Our bodies and roads would be always wet. There would be no need for umbrellas, and the housekeeper's temper would be sorely tried with the dripping walls.

A very easy experiment will show that where there is no dust there can be no fog. If common air be driven through a filter of cotton wool into an exhausted glass receiver, the vessel contains pure air without dust, the dust having been seized by the cotton wool. If a vessel containing common air be placed beside it, the eye is unable to detect any difference in the contents of the vessels, so very fine and invisible is the dust. If both vessels be connected with a boiler by means of pipes, and steam be passed into both, the observer will be astonished at the contrast presented. In the vessel containing common air the steam will be seen as soon as it enters, rising in a close white cloud; then a beautiful foggy mass will fill the vessel, so dense that it cannot be seen through. On the other hand, in the vessel containing the filtered, dustless air, the steam is not seen at all; though the eye be strained, no particles of moisture are discernible; there is no cloudiness whatever. In the one case, where there was the ordinary air impregnated with invisible dust, fog at once appeared; whereas in the other case, the absence of the dust prevented the water vapor from condensing into fog. Invisible dust, then, is required in the air for the production of fog, cloud, mist, snow, sleet, hail, haze, and rain, according to the temperature and pressure of the air.

The old theory of particles of water vapor combining with each other to form a cloud particle is now exploded. Dust is required as a free surface on which the vapor particles will condense. The fine particles of dust in the air attract the vapor particles and form fog particles. When there is abundance of dust in the air and little water vapor present, there is an overproportion of dust particles, and the fog particles are, in consequence, closely packed, but light in form and small in size, taking the more flimsy appearance of fog. But if the dust particles are fewer in proportion to the number of molecules of water vapor, each particle soon gets weighted, becomes visible, and falls in mist or rain.

This can be shown by experiment. Let a jet of steam be passed into a glass receiver containing common air, and it will be soon filled with dense fog. Shut off the steam and allow the fog to settle. The air again becomes clear. Admit more steam and the water particles will seize hold of the dust particles that previously escaped. Fog will be formed, but it will not be so dense. Again, shut off the steam and allow the fog to settle and the air to clear. Then admit some steam, and very likely the condensed vapor will fall as rain. If the experiment be often enough repeated, rain instead of fog will be formed, because there are comparatively few solid particles on which the moisture can condense. When, then, dust is present in large quantities, the condensed vapor produces a fog; there are so many particles of dust to which the vapor can adhere that each can only get a very small share—so small, in fact, that the weight of the dust is scarcely affected by the addition of the vapor—and the fog formed remains for a time suspended in the air, too light to fall to the ground. But when the number of dust particles is fewer, each particle can take hold of a greater space of the water vapor, and mist particles or even rain particles will be formed.

This principle that every fog particle has embosomed in it an invisible dust particle led Mr. Aitken to one of the most startling discoveries of our day—the enumeration of the dust particles of the air. Thirty years ago M. Pasteur succeeded in counting the organic particles in the air; these are comparatively few, whereas the number of inorganic particles is legion. Dr. Koch, Dr. Percy Frankland, and others have devoted considerable attention to the enumeration of the micro-organisms in the air, and Mr. A. Wynter Blyth, the public analyst in London, has done good service in counting the micro-organisms in the different kinds of water in the vicinity. Marvelous as are the results, still the process was comparatively easy. By generating the colonies in a prepared gelatin, the number of microbes can be easily ascertained.

But to attempt to count the inorganic dust seemed almost equal in audacity to the scaling of the heavens. The numbering of the dust of the air, like the numbering of the hairs of the head, was considered as one of the prerogatives of the Deity. Yet Mr. Aitken has counted the "gay motes that people the sunbeams." Though he could not enlarge the particles by a nutritive process, as in the case of the organic particles, he has been able to enlarge them by transferring them into fog particles, so as to be within the possibility of accurate enumeration. His plan is to dilute a definite small quantity of common air with a fixed large quantity of filtered, dustless air, and allow the mixture to be supersaturated by water vapor; the few particles of dust seize the moisture, become visible in drops, fall on a divided plate, and are there counted by means of a magnifying glass.

The instrument employed by Mr. Aitken has taken various forms; in fact, he has so far improved it that it can be carried in the coat pocket. But the original instrument, which we saw and used, is most easily described without the aid of diagrams. But, instead of his decimal system of measurements, we will use the ordinary system, that the dimensions may be more easily grasped by the general reader. Into a common glass flask of carafé shape, and flat bottomed, of thirty cubic inches capacity, are passed two small tubes, at the end of one of which is attached a square silver table, one inch long. A little water having been inserted, the flask is inverted, and the table is placed exactly one inch from the inverted bottom, so that the contents of the air above the table and below the bottom are one cubic inch.

The observing table has been divided into a hundred equal squares, and is highly polished, with the burnishing all in one direction, so that during the observations it appears dark, when the fine mist particles, falling on it, glisten, opal-like, with the reflected light, in order that they may be more easily counted. The tube to which the silver table is attached is connected with two stopcocks, one of which can admit a small measured portion of the air to be examined. The other tube in the flask is connected with an exhausting syringe, of ten cubic inches capacity. Over the flask is placed a covering colored black in the inside. In the top of this cover is inserted a powerful magnifying glass, through which the particles on the silver table can be easily seen and counted. A little to the side of this magnifier is an opening in the cover, through which light is concentrated on the silver table. This light, again, has had to pass through a spherical globe of water, in order to abstract the heat rays, which might vitiate the observations.

To perform the experiment the air in the flask is exhausted by the syringe. The flask is then filled with pure filtered air. One-tenth of a cubic inch of the air to be examined is then introduced into the flask, and mixed with the thirty cubic inches of dustless air. After one stroke of the syringe this mixed air is made to occupy an additional space of ten cubic inches; and this rarefying of the air so chills it that condensation of the water vapor takes place on the dust particles. The observer, looking through the magnifying glass upon the silver table, sees the mist particles fall like an opal shower on the table, and counts the number on a single square in two or three places, striking an average in his mind. Suppose the average number upon one of these squares were five, then on the whole table there would be 500; and these 500 mist particles contain the 500 dust particles which float invisibly in the cubic inch of mixed air above the table. But, as there are forty cubic inches of mixed air in the flask and syringe, the number of dust particles in the whole is 40 times 500 = 20,000; that is, there are 20,000 dust particles in the small quantity of common air (one-tenth of a cubic inch) which was introduced for examination; in other words, a cubic inch of that air contains 200,000 dust particles—nearly a quarter of a million.

By this process Mr. Aitken has been able to count 7,500,000 of dust particles in one cubic inch of the ordinary air of Glasgow. We counted with him 4,000,000 in a cubic inch of the air outside of the Royal Society Rooms, Princes Street, Edinburgh. Inside the room, after the fellows had met, for two hours, on a winter evening—the fire and gas having been burning for a considerable time—we found 6,500,000 in a cubic inch of the air four feet from the floor; but near the ceiling no fewer than 57,500,000 were counted in the cubic inch. He counted in one cubic inch of air immediately above a Bunsen flame the fabulous number of 489,000,000 of dust particles. The lowest number he ever counted was at Lucerne, in Switzerland: 3,500 in the cubic inch. On the summit of Ben Nevis the observer, using Mr. Aitken's apparatus, counted from 214,400 down to 840 in the cubic inch. But on the morning of July 21 last there was a most marvelous observation made. Though at the sea level the wind was steady, and the thermometer did not vary, at the summit the wind suddenly veered round to the opposite direction of that below, blowing out of a cyclone, and the temperature rose ten degrees. In consequence the extraordinarily low mean of only thirty-four dust particles to the cubic inch was observed.

We now come to the most pleasant of the investigations in connection with dust. The very brilliant sunsets which began in the autumn of 1883, and continued during successive seasons with gradually decreasing grandeur, have arrested the attention of the physicist as well as of the general observer. What is the cause of the brilliant coloring in these remarkable sunsets? What is the source of the immense wealth of the various shades of red which have been so universally admired? Gazing on a gorgeous sunset, the whole western heavens glowing with roseate hues, the observer sees the colors melting away before his eyes and becoming transformed into different hues. The clouds are of different sizes and of all shapes. Some float virgin-like in silver folds, others voyage in golden groups; some are embroidered with burning crimson, others are like "islands all lovely in an emerald sea." And when the flood of rosy light, as it deepens into bright crimson, brings out into bold relief the circlet of flaming mountain peaks, it is like a gorgeous transformation scene. Stranger still, when the sun sinks below the horizon, and a dull ashen gray has possessed the western heavens, what occasions the hectic flush on the eastern horizon? Gradually the clouds are tinged with light red from the eastern horizon all over the zenith; whence comes the coloring?

It is a strange coincidence that these remarkably fine sunsets have been since the tremendous eruptions at Krakatoa, in the Straits of Sunda. Along with the lava eruption there was ejected an enormous quantity of fine dust. The decks of vessels, hundreds of miles away, were covered with it. Mr. Verbreek computed that no less than 70,000 cubic yards of dust actually fell round the volcano. This will give an idea of the enormous quantity of dust still floating in the atmosphere, and drifting all over the world. In the upper atmosphere, too, there must always be dust, for without the dust no clouds could be formed to shield us from the sun's scorching rays; and of cosmic dust there must be a considerable quantity in the air, produced by the waste from the millions of meteors that daily fall into it. Mr. Aitken has ably shown that the brilliancy and variety of the coloring are due to the suspended dust in the atmosphere.

Observers of the gorgeous sunsets and afterglows have been most particularly struck with the immense wealth of the various shades and tints of red. Now, if the glowing colors are due to the presence of dust in the air, there must be somewhere a display of the colors complementary to the reds, because the dust acts by a selective dispersion of the colors. The small dust particles arrest the direct course of the rays of light and reflect them in all directions, but they principally reflect the rays of the violet end of the spectrum, while the red rays pass on almost unchecked. Overhead deep blue reigns in awe-inspiring glory. As the sun passes below the horizon, and the lower stratum of air, with its larger particles of dust which reflect light, ceases to be illuminated, the depth and fullness of the blue most intensely increase. This effect is produced by the very fine particles of dust in the sky overhead being unable to scatter any colors unless those of short wave lengths at the violet end of the spectrum. Thus we see, above, blue in its intensity without any of the red colors. When, however, the observer brings his eyes down in any direction except the west, he will see the blue mellowing into blue-green, green, and then rose color. And some of the most beautiful and delicate rose tints are formed by the air cooling and depositing its moisture on the particles of dust, increasing the size of the particles till they are sufficiently large to stop and spread the red rays, when the sky glows with a strange aurora-like light.

The dust theory of the splendor of sunset coloring is strengthened by the often glorious afterglows. The fiercely brilliant streaks of red have disappeared; over the mountain ridge a flush of orange hovers, and softens the approaching blue. The western hills, that once stood out bronzed against the glare of light, are somber hued. But suddenly, as by a fairy's wand, the roseate flush of beauty rises in the east, and stretches

its beautiful tints all over the sky. As the sun sinks, but before it ceases to shine on our atmosphere, the temperature of the air begins to fall, and its cooling is accompanied by an increase in the size of the particles floating in it by the condensation of the water vapor. The particles to the east lose the sun first, and are thus first cooled. Accordingly the rays in that direction are best sifted by the larger water-clad particles of dust, and the roseate coloring is there more distinct than in the north and south. As the sun sinks further, the particles overhead become cooler, and attract the water vapor; thus they increase in size, and thereby reflect the red rays. Here the red hues, at first visible in the east, slowly rise, pass overhead, and descend in the west to form the charming afterglow. Sometimes a flood of glory will roll once more along the summits of the hills, entrancing the attention of the artistic spectator.

All examinations of the volcanic dust lately collected from the atmosphere show that a great quantity of it is composed of small glassy crystals. An abundance of these would quite account for the peculiarity in the visibility of the first glow; and the evidence seems to indicate that the quantity of such crystals is sufficient to produce the result. When these are fully illuminated, they become in turn a source of illumination, and reflect their reddish light all around. In winter sunsets, the water-clad dust particles become frozen, and the peculiarly brilliant crimson is seen, coloring the dead beech leaves and red sandstone houses, and making them appear to be painted with vermilion.

If, then, there were no fine dust particles in the upper strata of the atmosphere, the sunset effect would be paler; if there were no large particles in the lower strata, the beautiful sunset effects would cease. In fact, if our atmosphere were perfectly void of dust particles, the sun's light would simply pass through without being seen, and soon after the sun dipped below the horizon total darkness would ensue. The length of our twilight, therefore, depends on the amount of dust in one form or another in our atmosphere. Not only, then, would a dustless atmosphere have no clouds, but there would be no charming sunsets, and no thought-inspiring twilights.

There is a generally prevalent fallacy that the coloring at sunrise or sunset is much finer when seen from the summit of a mountain than from a valley. To this matter Mr. Aitken has been giving some attention, and his observations point the very opposite way, corroborative of his dust theory. From the summit of the Rigi Kulm in Switzerland he saw several sunsets, but was disappointed with the flatness and weakness of the coloring; whereas in the valley, on the same evenings, careful observers were enchanted with the gorgeous display. The lower dusty humid air was the chief source of the color in the sunset effects. His opinion is strengthened by the fact that when from the summit he saw large cumulus clouds, the near ones were always snowy white, while it was only the distant ones that were tarnished yellow, showing that the light came to these clouds unchanged, and it was only the air between the far distant clouds and his eye that tarnished them yellow. On the mountain top it required a great distance to give even a slight coloring. The larger and more numerous dust particles in the air of the valley are, therefore, productive of more brilliant coloring in sunrise or sunset than the smaller and fewer particles on the mountain top.

It is now admitted that the inherent hue of water is blueness. Even distilled water has been proved to be almost exactly of the same tint as a solution of Prussian blue. This is corroborated by the fact that the purer the water is in nature, the bluer is the hue. But though the selective absorption of the water determines its blueness, it is the dust particles suspended in it which determine its brilliancy. If the water of the Mediterranean be taken from different places and examined by means of a concentrated beam of light, it is seen to hold in suspension millions of dust particles of different kinds. To this fine dust it owes its beautiful, brilliant, and varied coloring. Where there are few particles there is little light reflected, and the color of the water is deep blue; but where there are many particles more light is reflected, and the color is chalky blue green. Along its shores the Mediterranean washes the rocks and rubs off the minute solid particles, which make the water beautifully brilliant.

That this is the case can be illustrated. If a dark metal vessel be filled with a weak solution of Prussian blue, the water will appear quite dark and void of color. But if some fine white powder be thrown into the vessel, the water at once becomes of a brilliant blue color; if more powder be added, the brilliancy increases. This accounts for the changes of depth and brilliancy of color in the several shores of the Mediterranean. In Lake Como, where there is an entire absence of white dust particles, the water is of a deep blue color, but void of brilliancy; but, where the lake enters the river Adda, the increase of the current rubs down fine reflecting particles from the rocks; in consequence, there the water is of a finer blue. When the dust particles carried down by the Rhone spread out into the center of the Lake of Geneva, the color assumes the deeper blue, rivaling in brilliancy any water in the world.

The phenomenon called a haze puzzled investigators until Mr. Aitken explained it on the principle of the condensing power of dust particles. Haze is only an arrested form of condensation of water vapor. If one-half of a dusty pane of glass be cleaned in cold weather the clean part will remain undewed, while the dusty part is damp to the eye and greasy to the touch. Why is this?

Fit up an open box with two pipes, one for taking in water and the other for taking away the overflow. Inside fix a thermometer. Cover the top edge of the box with India rubber, and fix down with spring catches (so as to make the box water tight) a glass mirror, on which dust has been allowed to collect for some time. Clean the dust carefully off one half of the mirror, so that one half of the glass covering the box is clean and the other half dusty. Pour cold water through the pipe into the box, so as to lower the temperature of the mirror, and carefully observe when condensation begins on each of the halves, taking a note of the temperature. It will be found that the condensation of the water vapor appears on the dust particles before coming down to the natural dew point temperature of the clean glass. The difference between the two temperatures indicates the temperature above the dew point at which the dust condenses the water vapor. Mr. Aitken found that the condensing power of the dust in the air of a smoking room varied from 4° to 8° Fah. above the dew point, whenever that of the outer air varied from 3° to 5½°.

Moisture is, therefore, deposited on the dust particles of the air which is not saturated, and condensation takes place while the air is comparatively dry, before the temperature is lowered to the dew point. The clearest air, then, has some haze; and as the humidity increases, the thickness of the air increases. In all haze the temperature is above the dew point. And in all circumstances the haze can be accounted for by the condensing power of the dust particles in the atmosphere at a higher temperature than that required for the formation of fogs, or mists, or rain.

But whence comes the dust? Meteoric waste and volcanic *debris* have already been mentioned. On or near the sea the air is impregnated by the fine brine dust lashed by the waves and broken upon the rocks and vessel sides. But the most active of all substances as a fog producer in towns is burned sulphur. No less than three hundred and fifty tons of the products of the combustion of sulphur from the coal are thrown into the atmosphere of London every winter day. But the powerful deodorizing and antiseptic properties of the sulphur assist in sanitation; and it is better to bear the inconvenience of fogs than be subjected to the evils of a pestilence. At the same time it should be known that smoke particles can be deposited by the agency of electricity. If an electric discharge be passed through a jar containing smoke, the dust will be deposited so as to make the air clear. Lightning clears the air, restoring the devitalized oxygen and depositing the dust on the ground. Might it not, then, be possible for strong enough electrical discharges from several large voltaic batteries to attack the smoke in the air of large cities, and especially the fumes from chemical works, so as to bring down the dust in the form of rain instead of leaving it in the form of mystifying fog?

Organic germs also float in the air. Some are being vomited into the air from the pestilential hot beds of the lowest slums. In a filthy town no less than thirty millions of bacteria in a year will be deposited by the rain upon every square yard of surface. A man breathes thirty-six germs every minute in a close town and double that in a close bedroom. The wonder is how people escape sickness, though most of these germs are not deadly. In a healthy man, however, the warm lung surfaces repel the colder dust particles of all kinds, and the moisture evaporating from the surface of the air tubes helps the prevention of the dust clinging to the surface.

From this outline the reader will observe the increasing importance of careful attention to the influence of dust in the economy of nature. As a sickness bearer and a death bearer it must be attacked and rendered harmless; as a source of beauty unrivaled we must rejoice at its existence. The clouds that shelter us from the sun's scorching heat, the refreshing showers that clear the air and cheer the soil, the brilliancy of the deep blue sea and lake, the charms of twilight, and above all the glory of the colors of sunrise and sunset, are all dependent upon the existence of millions of dust particles which are within the power of man's enumeration. No more brilliant achievement has been made in the field of meteorology than during the past few years by the careful observation and inventive genius of Mr. Aitken in connection with the importance of dust in air and water.—*Longman's Magazine.*

KITE FLYING—THEORY AND PRACTICE.

THE TEXAS DYNAMITE KITES AND APPLICATION OF KITES TO AERIAL PHOTOGRAPHY.—KITE FLYING WITHOUT TAIL OR STRING.—SELF-FLYING KITES.

THE illustrated article, "Kite Photography," in the SCIENTIFIC AMERICAN SUPPLEMENT, November 7, 1891, No. 827, presents so many points of resemblance to experiments with kites which I have systematically conducted during several years past that, with a view to improving facilities in this line, I am induced to contribute the following to the very meager literature existing on the subject of kites.

With kite photography itself I have had no experience, as, with a photographic practice of many years, and the facilities afforded by my extensive operations with balloons, the necessity for or the availability of kites for aerial photography has not been pressing; but with kites bearing burdens I have been quite successful, and the application of the principles involved as an aid in kite photography is but a step.

The originating cause of my interest in kite flying is aerial navigation, and by successive steps I have adapted kites to fly without tails, to fly with considerable weight attached; and, finally, to fly without the restraint of the usual kite string, and, rising higher and higher, finally disappear miles in height and miles away on the verge of the distant horizon.

Theoretically, there should be no difficulty in attaining these results. Practically, there is as much difficulty as with a child learning to walk or a youth learning to manage a bicycle. In a word, it is the art of balancing.

Theoretically, a kite is acted upon by two forces, air pressure and gravitation, acting at right angles to each other, or horizontally and perpendicularly. The component of these forces, when the wind pressure on the plane equals the force of gravity exerted, is a line of 45°, acting at right angles to the restraining string of the kite and which prevents it from obeying its instinct to float, to rise, to drift backward, or to fall, as a simple movement.

Any modification of the form of the kite, adjustment of balance, or alteration of angle, will conduce to flight, fall, float, or drift.

The longer the kite, perpendicularly, the less it will float and the more it will drift.

The broader the kite, horizontally, the less it will drift, and the more it will float, other conditions being equal.

The more perpendicular the angle, the more the kite will drift or fall.

The more horizontal the angle, or surface, the more it will rise and the less it will drift. In the above statements it is assumed that the surface and the weight remain the same in each case.

The more horizontal the kite or the stronger the wind the greater weight it will carry.

As the force of gravity remains the same, practically, at all times, any increase of wind pressure tends to rise or float the kite if its weight is unchanged. Thus with a kite of given surface and angle and weight the wind may or may not be sufficient to float or raise it. If sufficient, it floats. If in excess, it rises.

Now, these principles being understood and applied, a kite may theoretically be operated at will, independent of tail or restraining string—the influence of the tail being to pull the kite backward and downward, and make its angle more perpendicular by adding weight below, while the influence of the restraining string is to pull forward and downward, while the weight of the kite pulls it down and the wind pulls it up.

Eliminating the restraining string and tail, the kite is subject to the constant pull of gravity downward and the varying influence of angle and wind speed, inducing the kite to rise, or fall, or float equipoised while it drifts backward.

Now, it is possible to establish such a relation among these conditions that the buoyant power will be the superior force and the kite will rise, against the force of gravity, and at a slight angle drift backward at a less speed than the wind.

It is a fact that all floating objects drift on the wind at a less speed than the current which bears them. This is true of balloons which weigh nothing, and of kites buoyed up by the wind currents, the form of body or opposing angles governing the "push" according to a not yet perfectly ascertained or understood formula.

Drift is a loss of force, and the more it can be avoided the more power is conserved.

Theoretically, then, the kite should be light, or possess much surface with little comparative weight. It should balance at the slightest possible angle, nearly horizontal, and its surface should be widespread, like the wings of a soaring bird. As a fact, I have obtained the best results with this model, but had great difficulty at first to induce it to fly at all, and was finally forced to attach a compromise tail, not a kite tail, but a bird-like tail, which, being flexible, vibrated or undulated by the vertical oscillations of the kite, and thus acted as a propeller, so that this kite actually moved against the wind.

Practically I solved the kite tail problem while endeavoring to fly a parachute kite or umbrella-like surface. Contrary to expectations, the kite refused to fly as I had planned, but "flopped over" and floated bottom side up, or convex side down, with the kite string running from its front end, and thus tending to tip it downward. Attaching the string to the convex side instead, near the top, and discarding the tail, seemed to satisfy this kite, as it retained its equilibrium without a tail, because the wind split equally on its breast bone and slipped backward on either side. This model will not fly without a string, but any kite will fly without the usual long ragged tail and tassel, if the wind can escape along a central channel rearward, and along an arm or wing on each side inclining slightly backward. This is the Chinese or Japanese type of kite.

The most practical form of kite for general purposes seems to be the six-sided. Those created by me as part of my apparatus for the government rainfall expedition, in Texas, were composed of an X, formed of two spruce sticks, each six feet long, tapering, with a top section of ¼ by ¼ inch, and bottom section of ¾ by ¼ inch, tacked flatwise together with a very small pin nail, and bound with hemp cord at the joining. Five inches below this crossing (which was about 2 feet from the top), was a similar piece of timber, but 14 inches shorter, and tapering each way, placed crosswise of the X, horizontally, so as to form a 5 inch triangle, which stiffened the frame more than if all crossed at one point. The outer end of each stick was creased with a knife and notched around, so that a hemp cord passed first through the crease and was "half-hitched" around each stick to prevent splitting. The kites were covered with red calico, pasted on tight, and bits of cloth were also pasted across the sticks where the kite strings attached. These strings were attached as long loops; one loop to the top sticks about 6 inches from their tips; one loop to the two bottom sticks, about 30 inches from the bottom; and one loop to the cross bar, about a foot from each end. All these loops were then gathered together and drawn through one hand as the kite lay on the ground, held in place by one foot on its crossing, and being adjusted carefully and equally to draw from *a point somewhere midway between the cross stick and top*, best attained by trial, were then tied together.

The kite was thus rather stiff and light at top, elastic and heavier at the bottom, and suspended at a point above its center of gravity and center of surface. To a loop at the bottom was usually hung a narrow strip of cloth, to afford greater steadiness in supporting the kite's burden of dynamite to be exploded. I have been thus particular to describe minutely this construction, because many have written me for this information. The first trial kite flown at Midland, Texas, escaped. I had built it all myself, as a model, and it had drawn up one ball of hemp twine, and an assistant was holding the string preparatory to running out another ball, when the cord parted at a flaw, and the kite flew into space. When last seen with a glass, it was estimated to be about 3 miles high and 8 or 10 miles away, a fading red dot in the distance.

For exploding dynamite a duplex insulated copper cable was used, contained in an inclosing sheath. A string 30 or 40 ft. long ran from the kite to a loop in the wire conductor, whose end hung down 20 ft. further and supported the dynamite, exploded always by a small cartridge fired by a hand dynamo or "blasting machine."

For aerial photography the camera should hang much nearer the kite or at the joining with the loop attachments, to avoid swinging like a pendulum.

These explosions had no effect on the kites. During my earlier experiments at the balloon farm, a dynamite cartridge hung to the kite's tail blew the tassel to pieces, and others exploded in mid-air within 50 ft. of 24 large windows in the rear of the farm mansion broke

no glass, whereas if exploded on the ground as near all might have broken.

In many instances the kites were flown tandem, the upper kite carrying the explosive, and the assistant kites each attached independently by 50 ft. of cord to the conducting cable as its weight became too heavy for the kite above to bear.

The chief obstacle to Texas kite flying was the wind, and larger kites than 6 ft. could seldom be flown.

In several instances the strong wind blew the anchored kites to the ground, their elastic frames bending backward to such an extent to relieve pressure that they were blown down like captive balloons. When the frames were re-enforced by binding two or three sticks together, the increased stiffness resulted in breaking the frame completely, because something had to give away, and the wind would not.

In ordinary light wind this kite floats well, is steadier than many other kinds I have tried, and would seem to be well adapted for photography. If hung very near its top, it is prone to advance upward and forward against the wind, till over and beyond the party holding the string, and literally floats on the air as if propelled by its fluttering triangular section at or near the bottom of the kite.

The obstacle to kite flying seems to be the varying pressure or force of the wind, necessitating a change in the angle of the attached cords to compensate for the changing angle of kite surface when restrained by a string, or, when free, an automatic balance or counterpoise is "indicated" by its symptoms. I am working out a "pendulum kite" whose oscillations shall cause it to fly with no more loss of power than is necessary to keep a clock pendulum swinging by an escapement. To fly a kite without a string in a good wind is not so hard, but to fly a kite with no wind and no string has yet to be accomplished.

CARL E. MYERS.
Aeronautical Engineer.

Balloon Farm, Frankfort, N. Y.

[The above article in its bearing on the rain-making experiments in the West is of special interest at the present time. We do not, however, agree with the writer in all his conclusions, especially as to the drift of objects in the air and as to the possibility of a kite flying in a horizontal wind without a string or its equivalent. In a wind containing a vertical component, objects could of course be carried upward, and this is often seen.—ED. SCIENTIFIC AMERICAN.]

PROF. PICTET'S LABORATORY AT BERLIN.

IT has often been remarked that purely scientific research frequently bears fruit of practical value. A fresh illustration of this fact is afforded by the work of Prof. Pictet, the eminent man of science of Geneva, who is turning to practical account the apparatus by which, in 1877, he first reduced hydrogen and oxygen to the liquid state. At Berlin, where he now resides, he has established, on the scale of a small factory, what he terms a "laboratoire à basses températures." The following account of the work carried on and the results obtained is taken from papers read by the Professor before different scientific societies of Berlin.

The refrigerating machinery, driven by several powerful steam engines, is intended to withdraw heat from the objects under observation, and to keep them at any temperature between —20° and —200° C. as long as may be required. Prof. Pictet's experience has led him to the conclusion that among the refrigerating agents known, such as rarefaction of gases, dissolution of salts, evaporation of liquids, the latter is to be preferred. A long course of research has enabled him to choose the most convenient from among the great number of suitable liquids. In order to avoid the great pressure required in handling the highly evaporative substances of lowest boiling point which serve to produce extreme cold, it is necessary to divide the difference of temperature into several stages. Each stage is fitted with especial apparatus consisting of an air pump worked by steam, which drains off the vapors of the liquid from the refrigerator, and forces them into a condenser, whence, reduced to the liquid state, they are again offered for evaporation in the refrigerator. Thus the liquid, without any loss beyond leakage, passes through a continuous circuit, and the operations can be carried on for any length of time. The liquid made use of for the first stage is the mixture of sulphurous acid and a small percentage of carbonic acid called "*liquide Pictet.*" It is condensed at a pressure of about two atmospheres in a spiral tube merely cooled by running water. Oxide of nitrogen (laughing gas) is the liquid chosen for the second stage. Its vapors are condensed in the same way at a pressure about five or six times as great in a tube maintained at about —80° by the action of the first circuit. As medium for a third stage, in which, however, continuous circulation has not yet been attempted, atmospheric air is employed, which, passes into the liquid state at a pressure of no more than about 75 atmospheres, provided the condenser is kept at —135° by the first two circuits. The evaporation of the liquefied air causes the thermometer to fall below —200°.

By this combination quite new conditions for investigating the properties of matter are realized. In various branches of science new and surprising facts have already been brought to light. Many laws and observations will have to be re-examined and altered with regard to changes at an extremely low temperature.

For instance, a remarkable difference was noted in the radiation of heat. Material considered a non-conductor of heat does not appear to affect much the passage of heat into a body cooled down to below —100°. Or, to state the fact, according to Prof. Pictet's view: "The slow oscillations of matter, which constitute the lowest degrees of heat, pass more readily through the obstruction of a so-called non-conductor than those corresponding to a higher temperature, just as the less intense undulations of the red light are better able to penetrate clouds of dust or vapor than those of the blue." If the natural rise of temperature in the refrigerator, starting from —135°, is noted in a tracing, and afterward the same refrigerator carefully packed in a covering of cotton wool of more than half a yard in thickness, and cooled down afresh, and the rise of temperature again marked, on comparing the tracings hardly any difference will be found in the two curves up to —100°, and only a very slight deviation even up to —50°. On this ground it is clear that the utmost limit of cold that can possibly be attained is not much lower than that reached in the famous experiment of liquefaction of hydrogen. The quantity of warmth which hourly floods a cylinder 1,250 mm. high by 210 mm. wide (the size of the refrigerator), at —80°, is no less than 600 calories, and no packing will keep it out. At a lower temperature, the radiation being even greater, the power of the machinery intended to draw off still more heat would have to be enormous. And as —273° is absolute zero, the utmost Prof. Pictet judges to be attainable is about —255°.

As an example of the surprising methods which the refrigerating machine permits the investigator to employ, it may be mentioned that, in order to measure the elasticity of mercury, Prof. Paalzow had the metal cast into the shape of a tuning fork, and frozen hard enough for the purpose in view. On this occasion it appeared that quicksilver can be shown in a crystallized state, the crystals being of a beautiful fern-like appearance.

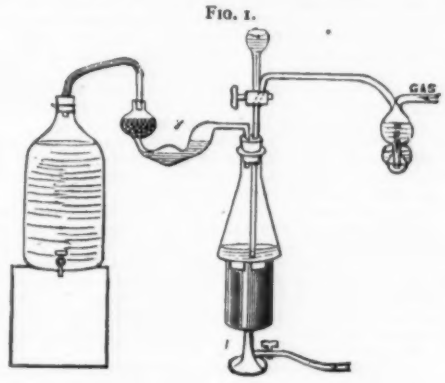
Glycerine was likewise made to crystallize; and cognac, after having been frozen, was found to possess that peculiar mellowness commonly only attained by long keeping.

But the most important application of the refrigerating machinery has been the purification of chloroform, undertaken by Prof. Pictet at the instance of Prof. Liebreich, of the Pharmacological Institute, Berlin. Chloroform has hitherto been considered a most unstable and easily defiled substance. The action of sunlight, the slight impurities retained from different processes of manufacture, perhaps the mere settling down during protracted storage, have invariably resulted in a more or less marked decomposition. By the simple process of crystallization this unstableness is got rid of, and a practically unchangeable liquid is produced. The crystals begin to form at —68°, first covering the bottom of the vessel, and gradually filling it up to within one-fifth of the whole volume. This residue being drained off, the frozen part is allowed to melt under cover, so as to exclude the atmospheric moisture. Chloroform thus refined has, by way of testing its durability, remained exposed on the roof in a light brown bottle from November till June without the slightest sign of decomposition.

Prof. Pictet has already taken steps to introduce his process into manufacture, and proposes to apply the principle to various other chemical and technical objects. Sulphurous ether, for instance, has by a similar process been produced in a hitherto unknown degree of purity. At the same time, the Professor continues eagerly to pursue the various purely scientific inquiries with which he started. R. DU BOIS-REYMOND.

—*Nature.*

FIG. 1.



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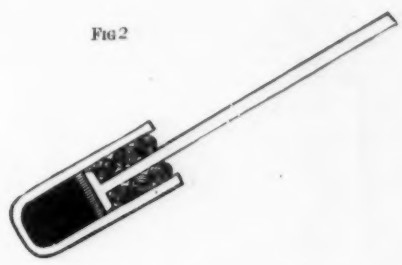
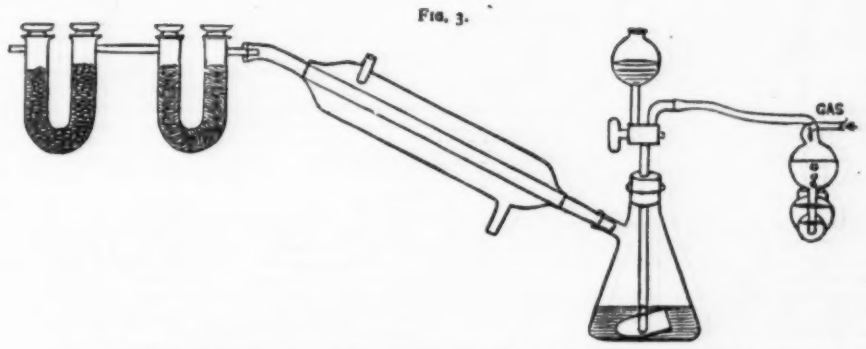


FIG. 3.



APPARATUS FOR THE ESTIMATION OF SULPHUR.

ON THE ESTIMATION OF SULPHUR.

By GEORGE CRAIG.

EVOLUTION methods, whereby the substance to be determined is first of all eliminated as a gas from the material under examination, must always be more satisfactory than gravimetric methods, although no greater degree of accuracy is attained thereby. Such, for instance, is the estimation of NH_3 by liberation with alkali, with subsequent condensation and titration with standard acid.

Sulphur, when it exists as monosulphide, decomposable by HCl, is certainly best determined after expulsion as H_2S.

Pig iron and steel, even when containing Cu, yield all their S as H_2S on treatment with HCl, which, as I proposed in 1881, may be completely oxidized to SO_3 by passing the gases through ammoniacal H_2O_2.

In blast furnace slags the S exists wholly as CaS, which, it must be borne in mind, readily oxidizes when the finely ground slag, especially from hematite iron, is kept for any time. The only correct method where by it can be estimated, unless with the expenditure of much time and labor, is by decomposing the slag with HCl and estimating the S in the H_2S evolved. For this purpose I use the apparatus shown in Fig. 1, which scarcely needs explanation. 20 grs. of finely ground slag is heated with 1 oz. of boiled water, and the air expelled from the flask by a current of coal gas which has been passed through a mixture of KHO and H_2O_2 in the Liebig's bulbs shown. When boiling agitate so that the slag is all in suspension, and add HCl by means of the three-way stopcock, continuing agitation until the slag is all decomposed, which takes place in a few seconds; boil and pass a current of the purified coal gas through the apparatus with the aid of the aspirator. The nitrogen bulb—containing 100 grs. H_2O_2, 200 grs. NH_4HO—is preferably made, as in figure, by cutting the escape tube nearly at the bulb, widening the orifice, introducing some glass beads, and connecting with I. R. tubing as shown. The contents of the nitrogen bulb are washed into a small beaker, heated to boiling, acidified, and the SO_3 established as $BaSO_4$ as usual.

It is now more than a year since it occurred to me that compound sulphides, such as pyrites, etc., might be made amenable to this evolution process also by the simple preliminary operation of heating with zinc dust, and so reducing to the state of monosulphides. In a recent number of the *Chemical News* there is a translation from the *Berichte* of an almost identical process; but as reduction with zinc is very much simpler, a description of the method I employed may be of interest.

Ordinary zinc dust, after passing through a fine sieve, is heated to redness to expel moisture and occluded hydrogen, and allowed to cool out of contact with air. A tube of Bohemian glass closed at one end suits admirably for this purpose.

Ten or twenty grains of the pyrites in fine powder are weighed into a small ignition tube of Bohemian glass (2 in. long by ½ in. diameter), then five times its weight of zinc dust added, intimately mixed with a platinum wire, the surface leveled by tapping gently, and covered with a layer of zinc dust. A stout glass rod about 8 in. long had one end flattened out into a disk that entered easily into the little decomposing tube. This was introduced until the disk rested lightly on the covering layer of zinc dust, and the upper portion of the tube was packed with asbestos yarn firmly enough to enable the glass rod to serve as a support (Fig. 2). The tube and contents is then revolved over an Argand flame until thoroughly heated, and then over a Bunsen flame. In a few seconds bright incandescence takes place, and after maintaining a red heat for thirty seconds longer it is withdrawn gradually, revolving all the while, and then allowed to cool.

When carried out in this manner practically no sulphate is reduced, but when maintained at a red heat for five to ten minutes all sulphates are reduced. Apropos of sulphates in pyrites, I have not seen it recorded that a considerable amount of pyrites may be oxidized while grinding the sample in the agate mortar; in the dark a red glow follows the track of the pestle.

After withdrawing the support and asbestos packing the tube is dropped into a 4 oz. conical flask with side tube, connected with condenser and U-tubes, as shown in Fig. 3. The first U-tube contains $CaCl_2$, and the second is filled with glass beads and contains 100 grs. of NaHO solution (1,000 grs. and 1,500 grs. water). 1 oz. boiled water is added, and a current of purified coal gas passed through apparatus. Heat is applied and the HCl gradually run in until decomposed, contents boiled, and apparatus washed out with a current of gas. I preferred to estimate the H_2S by washing out the U-tube (without removing stoppers) into a beaker, adding excess of $FeCl_3$, agitating, acidifying with HCl delivered at bottom of liquid by means of a pipette, heating until all FeS decomposed, and titrating with bichrome. The ideal process would be to accurately weigh the NaHO solution and titrate after

absorption with acid, using an indicator neutral to NaHS or Na_2S. The arsenic I found was completely expelled, so that not a trace could be detected in the combined residues from a number of experiments.—*Chem. News.*

APPARATUS FOR THE CONSTANT GENERATION OF GASES.

By R. ULBRIGHT and O. FORRSTER.

THE authors are in the habit of drying feeding cakes, and their ethereal extracts, in a current of carbonic anhydride. As the Kipp's apparatus requires a good deal of attention, and wants often recharging, they have now constructed an apparatus which will be found to answer better, and can be left for a long time to itself.

Fig. 1 represents the apparatus. A is a glass cylinder 1 meter in height and 10 cm. in diameter, filled with small lumps of marble. The top of the cylinder is fitted with a trebly perforated ground glass stopper A^1, and the lower part is connected with the tube *b*. Through tube *a* (see Fig. 2), which can be closed by the stopcock, and the lower part of which is drawn out into four points, hydrochloric acid contained in the reservoir B is allowed to slowly drop on to the marble. Having to traverse such a long distance, the acid is almost completely spent before it reaches the bottom. The solution of the calcium chloride flows through the tube *b* into the flask C, which must contain sufficient fluid to prevent escape of gas. The tube must have a sufficiently large diameter so as never to be filled, and consequently not to act as a siphon. The cylinder A is connected with the reservoir B by means of the tube β (Fig. 2), which in turn is connected air tight with *c* by means of an India rubber tube, in order that the pressure of the gas in both tubes shall be the same.

FIG. 1.

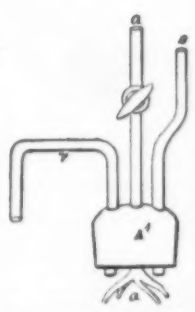


FIG. 2.—A CONSTANT GENERATOR OF GASES.

The carbonic acid finally escapes through the tube *y* (Fig. 2), and is passed through a wash bottle. If the marble wants replenishing, all the analyst has to do is to remove the stoppers *a* and *c*.

The same apparatus may of course also be used for generating other gases, such as hydrogen sulphide.—*Chem. Zeit., Jour. S. Chem. Ind.*

THE PIERCE PROCESS FOR THE PRODUCTION OF CHARCOAL, WOOD ALCOHOL AND ACETIC ACID.

By W. L. DUDLEY.

THE special advantages of this process, which was devised in its original form in 1876, consist in the larger yield of charcoal which is obtained from the wood carbonized, and in the far smaller loss of by-products, the charcoal being also of better quality than any otherwise prepared. The average amount of charcoal obtained by the other processes is 17·5 per cent. of the wood employed, while the yield in this case is shown in the table:

	Per Cent.
Charcoal	25·30
Methyl alcohol	0·75
Acetic acid	1·00
Tar	4·00
Water	45·95
Permanent gases	23·00
	100·00

The wood is heated in brick kilns, shaped like a beehive, of 32 feet diameter, and 16 feet height in the center, by means of the combustion of the permanent gases produced during a previous operation. During the drying, the steam is allowed to escape through a hole in the top of the kiln, but when the carbonization begins, the hole is stopped up, and the products of distillation are drawn away by an exhaust fan into a large main leading into a series of condensers, where the acetic acid, tar, and alcohol are deposited. The uncondensed gases are then forced back into the kilns, where they are mixed with the requisite amount of air, by means of a steam jet, and burned in the furnaces. In this way, the carbonic acid gas and the water vapor being decomposed into carbonic oxide and hydrogen respectively, more gas is accumulated than is needed for carbonizing, and in fact more than sufficient to yield steam for the engines driving the fans, etc., and for the stills in the alcohol house. The liquor from the condensers is allowed to stand in tanks, and when the tar has subsided, it is drawn off and neutralized with milk of lime. The neutral liquor is distilled in wooden stills by dry steam to obtain the alcohol, which is afterward twice rectified, and the residue is evaporated and the crude calcium acetate sold as such. The tar is chiefly employed in painting the gas mains, condensers, etc.

A complete plant on this system consists of 48 kilns, which hold 55 cords of wood each, and take from 12 to 18 hours for drying, and six to eight days for carbonizing. The kilns are set in three batteries of 16 each, each battery having its own fan and set of five condensers in series, the fan being placed after the first condenser. These are wooden boxes about 4 feet square and 14 feet long, filled with copper tubes, in which the condensing water circulates. The alcohol house contains eight "primary" stills, for the first distillation, four "intermediate," and two "shipping" stills. Of these, the primary are made of wood, the other being of sheet iron, and fitted with "weak liquor" condenser, consisting of a worm passing through a trough filled with water at a temperature of 80°—95° C., to strengthen the alcohol as much as possible. The alcohol having to pass through two of these baths, often becomes of as much as 90 per cent. strength, in which case it is diluted with water to 82 per cent. for shipment.—*J. Analyt. and Applied Chem.*

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